AMERICAN SCIENCE SERIES

BOTANY

FOR

HIGH SCHOOLS AND COLLEGES

BY

CHARLES E. BESSEY, PH.D.,

PROFESSOR OF BOTANY IN THE UNIVERSITY OF NEBRASKA; FORMERLY PROFESSOR OF BOTANY IN THE IOWA AGRICULTURAL COLLEGE; ASSOCIATE EDITOR OF THE "AMERICAN NATURALIST" (DEPARTMENT OF BOTANY)

SIXTH EDITION, REVISED

NEW YORK
HENRY HOLT AND COMPANY
1889

PREFACE.

THIS book is designed to serve as an Introduction to the Study of Plants. It does not profess to give a complete account of the Vegetable Kingdom, but only such an outline as will best subserve the purposes of the work.

In its preparation there have been kept in view the wants of the large number, in the schools and out, who wish to obtain, as a branch of a liberal culture, a general knowledge of the structure of plants, with some idea as to their classification into the larger divisions and subdivisions of the Vegetable Kingdom. For this class of students and general readers, what is here given will in most cases be amply sufficient to enable any one to understand the greater part of the current biological literature, in so far as it relates to vegetable organisms. For the student who desires to pursue the subject further, or who intends to make botany a special study, this book aims to lead him to become himself an observer and investigator, and thus to obtain at first hand his knowledge of the anatomy and physiology of plants: accordingly the presentation of the matter has been made such as to fit the book for constant use in the Laboratory, the text supplying the outline sketch, which may be filled up by each student, with the aid of the scalpel and compound microscope.

This book is an expansion and considerable modification of the material of several courses of lectures

annually delivered to college students. In general plan, Part I. follows pretty nearly that of Sachs' admirable "Lehrbuch," and in many instances it has seemed to me that I could not do better than to adopt the particular treatment which a subject has received at the hands of the distinguished German botanist. This has been rendered possible through the liberality of my publishers, and the courtesy of Engelmann of Leipzig, the publisher of many of Sachs' works, by which many of the cuts of the "Lehrbuch" are here reproduced. This book will thus, to a considerable extent, serve as an introduction to that work. Free use has also been made of the recent works of De Bary, Hofmeister, Strasburger, Nägeli, Schwendener, and others, to whose writings numerous references are made.

In Part II. the general disposition of the lower plants is a considerable modification of that proposed by Sachs; that of the higher plants is made to conform to the system of classification in vogue in this country and in England, as outlined in Dr. J. D. Hooker's "Synopsis of the Classes, Sub-classes, Cohorts and Orders," in the English edition of Le Maout and Decaisne's "Traité Générale de Botanique," and as given much more fully in Bentham and Hooker's still unfinished "Genera Plantarum." The notes upon the economic values of the more important plants of each order are based upon my own lectures upon Economic Botany. I have also freely used the similar notes in Le Maout and Decaisne's work, cited above; Balfour's "Class-Book of Botany," Archer's "Economic Botany," Smith's "Domestic Botany," Laslett's "Timber and Timber Trees," etc., etc.

Necessarily, there is but little that is really new in a treatise like this. Aside from a more or less important and original arrangement of the matter, so as to

secure a more logical presentation of the subject, there are but two considerable innovations, consisting (I.) in the recognition (in Chapter VI.) of seven quite well marked kinds of tissue. In this, however, while not adopting De Bary's classification, I have followed his method of treating the subject, as given in his recent work on the comparative anatomy of plants ("Vergleichende Anatomie der Vegetationsorgane der Phanerogamen und Farne.") (II.) The second considerable innovation occurs in Part II.; it consists in raising the Protophyta, Zygosporeæ, Oosporeæ and Carposporeæ to the dignity of Primary Divisions of the vegetable kingdom, co-ordinate with the Bryophyta, Pteridophyta and Phanerogamia. The usefulness of both of these departures from the common practice has been subjected to the test of the laboratory, and the lecture and class-room, with the most satisfactory results; and I am led to hope that in the hands of others they may also serve to give a clearer and more accurate notion of the structure of plants. Should they do this they will need no further apology or defense.

Of the illustrations, many are entirely new; many others have been re-drawn, from various sources, with slight modifications, expressly for this work, and all from other sources are specially acknowledged in their places.

I desire here to acknowledge my indebtedness to Dr. Asa Gray, whom it is an honor to own as my sometime teacher, for kindly aid and counsel in the preparation of the lectures upon which this work is based; and in the same way I am indebted to Dr. G. L. Goodale, Dr. W. G. Farlow and Professor A. N. Prentiss. For aid in the immediate preparation of the material for the press, acknowledgment is due many of my personal friends: Mr. J. C. Arthur furnished the original drawings of the water-pores of

Fuchsia, and of various tissues of *Echinocystis;* Professor H. L. Smith, of Hobart College, New York, contributed the sketch of the classification of the Diatomaceæ ; Dr. T. F. Allen furnished a synopsis of the classification of the Characeæ ; Dr. B. D. Halsted also furnished material and notes upon our native species of Characeæ ; my colleague, Professor W. H. Wynn, kindly determined some of the more difficult etymologies; to my wife I am deeply indebted for efficient aid in the laborious tasks of proof-reading and indexing.

Should this book serve to interest the student in the study of plants as living things, should it succeed in directing him rather to the plants themselves than to the books which have been written about them, should it contribute somewhat to the general reader's knowledge of the structure and relationship of the plants around him, the objects kept in view in its preparation will have been attained.

C. E. B.

April 12, 1880.

PREFACE TO THE SIXTH EDITION.

The second, third, and fourth editions, appearing respectively in 1881, 1883, and 1885, contained a considerable number of corrections and additions. In the fifth edition (1888) that modification of the second, third, and fourth branches of the Vegetable Kingdom (Zygophyta, Oophyta, and Carpophyta) previously used in the "Essentials of Botany," was adopted, and a number of important paragraphs were added as foot-notes. The changes in the present edition, a dozen or so in number, include some additions and a number of corrections.

C. E. B.

University of Nebraska,
Lincoln, *April* 18, 1889.

CONTENTS.

PART I. GENERAL ANATOMY AND PHYSIOLOGY.

CHAPTER I.

Protoplasm.

CHAPTER II.

The Plant-Cell.

CHAPTER III.

The Cell-Wall.

CHAPTER IV.

The Formation of New Cells.

CHAPTER V.

The Products of the Cell.

CHAPTER VI.

Tissues.

CHAPTER VII.

The Tissue Systems.

CHAPTER VIII.

CHAPTER IX.

The Plant-Body.

CHAPTER X.

The Chemical Constituents of Plants.

CHAPTER XI.

The Chemical Processes in the Plant.

CHAPTER XII.

The Relations of Plants to External Agents.

PART II. SPECIAL ANATOMY AND PHYSIOLOGY.

CHAPTER XIII.

Classification.

CHAPTER XIV.

The Protophyta.

CHAPTER XV.

The Zygophyta.

CHAPTER XVI.

The Oophyta.

CHAPTER XVII.

The Carpophyta.

CHAPTER XVIII.

The Bryophyta.

CHAPTER XIX.

The Pteridophyta.

CHAPTER XX.

The Phanerogamia.

CHAPTER XXI.

Concluding Observations.

BOTANY.

PART I.

GENERAL ANATOMY AND PHYSIOLOGY.

CHAPTER I.

PROTOPLASM.

1.—If we examine a thin slice of any growing part of a plant (Fig. 1) under a microscope of a moderately high power (400 to 500 diameters), there may be seen large numbers of cavities which are more or less filled with an almost transparent semi-fluid substance. In very young parts, as in buds and the tips of roots, this substance entirely fills the cavities, and makes up almost the whole mass, while in older parts it occurs in less quantity, and usually disappears in quite old tissues. This substance is the *living portion of the plant*, the active, vital thing which gives to it its sensibility to heat, cold, and other agents, and the power of moving, of appropriating food, and of increasing its size; it is, in fact, *that which is sensitive, which moves, appropriates food, and increases in size.* This sensitive, moving, assimilating, and growing substance is named PROTOPLASM.*

It is a fact of great biological interest that in animals the essential constituent of all living parts is a substance similar to the protoplasm of plants. We cannot distinguish the two by any chemical or physical tests, and can only say that, taken as a whole, the protoplasm of plants

* So named by its discoverer, Dr. Hugo Von Mohl, in 1846. It is the Bioplasm of Dr. Lionel Beale and his followers.

differs from that of animals in its secretions. And yet these secretions are not strictly confined to plants ; cellulose, starch, chlorophyll, and other products of vegetable protoplasm formerly regarded as peculiar to plants are now known to occur in undoubted animals. Botanists and zoologists have labored long in vain to discover absolute differences between the animal and the vegetable kingdoms. between the higher plants and the higher animals there are great and constant differences.: in none of the higher animals, for example, is chlorophyll produced ; but in the lower orders of both kingdoms not one of the differences observed to hold between the higher plants and animals exists.

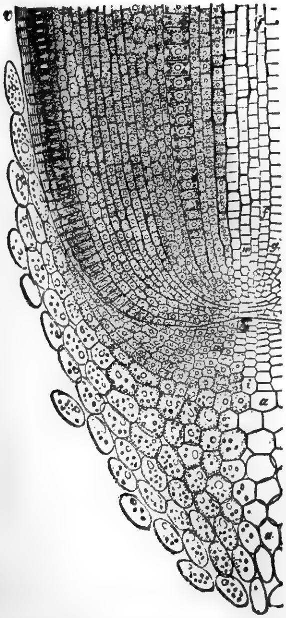


Fig. 1.—A little more than half of a longitudinal section of the apex of a young root of the Indian corn. The part above *s* is the body of the root, that below it is the root-cap ; *v*, thick outer wall of the epidermis; *m* young pith-cells ; *f*, young wood-cells ; *g*, a young vessel ; *s*, *i*, inner younger part of root-cap ; *a*, *a*, outer older part of root-cap.—After Sachs.

2.—The exact **chemical composition** of protoplasm has not hitherto been made out, but it is known to be an albuminous, watery substance, combined with a small quantity of ash. It is probably a complex mixture of chemical compounds, and not a single compound. It contains at some time or another all the chemical constituents of plants. Oil, granules of starch, and other organic substances are frequently present in it, but they are to be regarded as products rather than proper constituents of protoplasm.

(*a*) Water makes up a considerable part of the bulk of ordinary protoplasm, and is much more abundant in its active than in its dormant conditions. In the protoplasm of *Fuligo varians* (one of the Slime Moulds) just before the formation of its spores there is 70 per cent of water ; in dry seeds, on the other hand, the amount is not more than about 8 to 10 per cent.

(*b*) As to its molecular constitution, Strasburger holds* that protoplasm is composed of minute solid particles (not, however, of a crystalline form), separated from each other by layers of water (see Cell-wall,

* "Studien über Protoplasma," 1876.

paragraph 37, and Starch, paragraph 69). The thicker the layers of water are, the more watery is the protoplasm, and *vice versa.*

(*c*) *Tests.* 1. If a protoplasmic mass is moistened with a solution of iodine, it at once assumes a deep yellow or brown color.

2. If treated with a solution of copper sulphate and afterwards with potash, it assumes a dark violet color.

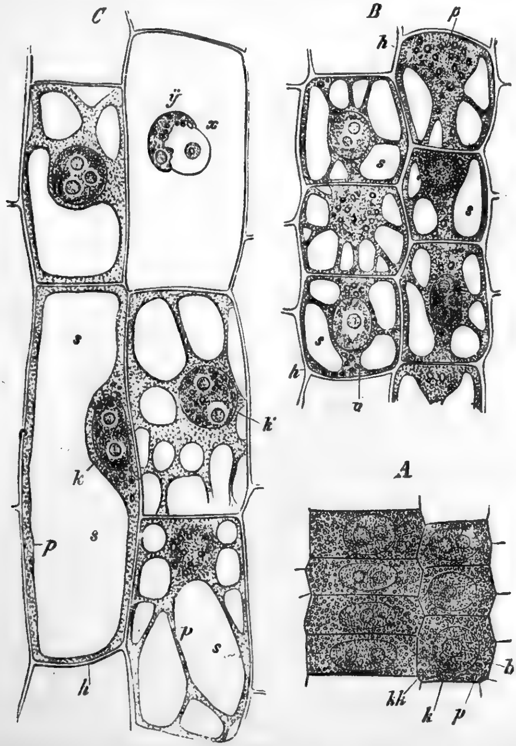


Fig. 2.—Parenchyma cells from the central cortical layer of the root of *Fritillaria imperialis*, longitudinal sections. *A*, very young cells lying close above the apex of the root, still without cell sap or vacuoles. *B*, cells of the same description about two millimetres above the apex of the root; by the entrance of cell sap the vacuoles *s*, *s*, *s* have been formed. *C*, cells of the same description about seven to eight millimetres above the apex of the root. In all the figures, *h*, cell-wall; *p*, protoplasm; *k*, nucleus; *k k*, nucleoli; *s*, vacuoles; *x y*, swelling of the nucleus under the influence of the water in preparing the specimen. × 500.—After Sachs.

3. Treated with a solution of sugar, and afterwards with sulphuric acid, it becomes rose-red.

4. The presence of protoplasm may be demonstrated in a tissue by the application of various staining fluids, as magenta, carmine, etc.

5. In a dilute solution of potash protoplasm is dissolved; if, however, the solution is concentrated, the form of the protoplasm remains unaltered for weeks, but upon the addition of water it at once dissolves.

6. Protoplasm coagulates upon the application of heat (50 degrees Centigrade), or when immersed in alcohol or dilute mineral acids.

3.—In consistence protoplasm is a soft-solid substance, varying from an almost perfect fluidity on the one hand to a considerable degree of hardness and even brittleness on the other. This difference in consistence is mainly due to the varying amounts of water imbibed by it, hence the same mass may at different times vary greatly in this regard. Generally there may be seen in protoplasm a large number of minute granules enclosed in a transparent medium (Fig. 2, A); in some instances, however, the granules are entirely wanting, or nearly so. By the withdrawal of these granules for a little distance from the surface toward the centre, a mass of granular protoplasm (the endoplasm) may appear to be surrounded by a hyaline envelope, the protoplasmic skin, or ectoplasm (the *Hautschicht* of Pringsheim, and *Hauptplasma* of Strasburger) (Fig. 3). It is almost always formed when protoplasm is exposed in water or air; but it, or something very much like it, appears to be generally present, even in closed cells.

Fig. 3.—Optical section of a retracting branch of a large plasmodium of *Fuligo varians* (*Æthalium septicum* of authors); the narrow inner granular mass of protoplasm is seen to be surrounded by a broad hyaline portion, the ectoplasm, which in this case is radially streaked. Above is seen a fragment of the body of the plasmodium; its granular protoplasm (endoplasm) is also surrounded by a hyaline envelope. × 200.—After Hofmeister.

(*a*) The fine granules are probably not proper constituents of protoplasm, but finely divided assimilated food-materials immersed in the proper protoplasm, which is itself colorless and transparent. Protoplasm destitute of granules may be found in the cotyledons of the bean (*Phaseolus*). In other cases, *e.g.*, in the zygospores of *Spirogyra*, the granular and coloring matters are so abundant that the hyaline basis can no longer be distinguished.

(*b*) Strasburger* maintains that the hyaline envelope is not simply a portion of the basis or ground substance of the protoplasm deprived of its granules, but that it is a definite modification of it, and endowed with various properties quite distinct from those of the ground substance.

4.—Active protoplasm possesses the power of imbibing water into its substance, and as a consequence, of increasing its mass. This power varies with the changes in external, and also in internal conditions; many seeds, for example, which do not swell up (through absorbing water) in cold water, will do so when placed in that of a higher temperature; but in some seeds it appears that imbibition of water will not take place until after a period of rest.

5.—When the amount of water imbibed is so great that the protoplasm may be said to be more than saturated with it, the excess is separated within the protoplasmic mass in the form of rounded drops, termed **Vacuoles** (*Vacuoli*). In closed cells these may become so large and abundant as to be separated only by thin plates of the protoplasm (Fig. 2, B). As such vacuoles become still larger, the plates are broken through, and eventually we may have but one large vacuole surrounded by a thin layer of protoplasm, which lines the interior of the cell wall (Fig 2, C). In this way some masses of protoplasm assume a bladder-like or vesicular form, so unlike their original form that until very recently their real nature has not been understood.† Frequently when the plates which separate vacuoles break down, instead of breaking entirely away they become pierced with several large openings, leaving strings or bands of protoplasm which extend across the cavity.

Occasionally, when vacuoles unite, small masses of the protoplasm which previously separated them become detached as free rounded

---

* "Studien über Protoplasma," 1876. See also *Qr. Jour. Mic. Science*, 1877, p. 124 et seq.

† Von Mohl gave to this layer the name Primordial Utricle, and it is still frequently used, but the term is objectionable, and Sachs' name of Protoplasmic Sac is to be preferred. Treatment with glycerine, strong alcohol, or any other substance which removes the water, will cause the protoplasmic sac to contract and become visible.

masses in the large vacuole; these again may produce vacuoles within themselves, and thus give rise to a peculiar and at first sight perplexing structure (Fig. 4).

6.—The most remarkable peculiarity of living protoplasm is its *physical activity*. When the proper conditions are present, a living mass of protoplasm is apparently never at rest, but, on the contrary, continually altering its shape and changing the position of its constituent parts. The movements are all of the same general nature; each one may be regarded as the aggregate result of the chemical and physical changes taking place in the substance of the protoplasm.

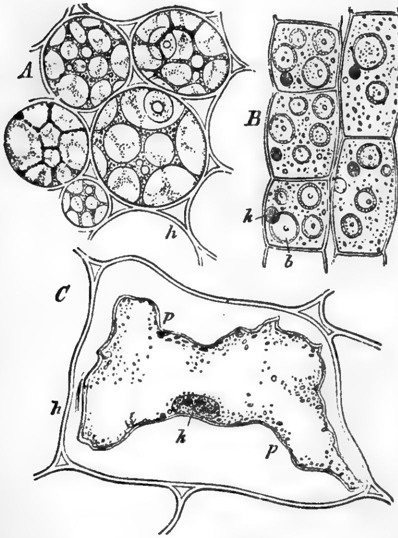


Fig. 4.—Forms of the protoplasm contained in cells. *A* and *B*, of Indian Corn (*Zea mais*); *A*, cells from the first leaf-sheath of a germinating plant, showing the frothy condition of the protoplasm, the many vacuoles separated by thin plates. *B*, cells from the first internode of the germinating plant; the protoplasm is broken up into many rounded masses, in each of which there is a vacuole, *b*; these are the so-called "sap-vesicles." *C*, a cell from the tuber of the Jerusalem Artichoke (*Helianthus tuberosus*) after the action of iodine and dilute sulphuric acid; *h*, cell-wall; *k*, nucleus; *p*, contracted protoplasm.—After Sachs.

We may study the activity of protoplasm under two conditions, which will give us the two cases. (1.) The Activity of Naked Protoplasm, and (2.) The Activity of Protoplasm enclosed in a Cell-wall.

7.—The Activity of Naked Protoplasm. The low organisms known as the *Myxomycetes*, or Slime Moulds, present the best examples of the activity of naked vegetable protoplasm. In their plasmodia (as the masses of naked protoplasm are called), many kinds of movements may be observed, the commonest of which is *streaming*. In plasmodia composed of thin (*i.e.*, watery) protoplasm, streams or currents of the latter may be seen running in various directions

(Fig. 5). The streams are made clearly visible by the motion of the granules which are carried along by the moving hyaline portion of the protoplasm. After running in one

Fig. 5.—A small mass of the naked protoplasm (*plasmodium*) of *Didymium serpula*; the arrows show the direction of the currents. × 80.—After Hofmeister.

direction for some minutes (about five) the current stops, and then it usually sets in an exactly opposite direction for about the same length of time, and carries back the previously moved protoplasm.

The formation of the new current may be explained as follows: Let A............B be a stream in which the movement is from A to B; clearly there will be an aggregation of protoplasm about B. When the current in the direction A B stops, the new one, in the reverse direction, B A, begins at A, by the movement toward it of the particles nearest to it; next the particles further off move toward A; after this, those still further off, and so on. The current *extends backward*. So, too, when a stream begins *de novo*, it is propagated backward from the point of beginning.

8.—Mass-Movement (Amœba-Movement). In the flowing back and forth in the streams the movement may be greater in one direction than in the other; this causes a slow motion of the whole plasmodium in the direction of the greatest movement. When this takes place in the case of streams which begin in the margin of the plasmodium, protuberances of various shapes arise; these may be extended into branches (*pseudopodia*), which may again be branched one or more times. By the anastomosing of these branches a complex moving and changing network is formed. (See Fig. 140, page 208) There is possibly to be separated from the above-described mass-movement that more or less rapid change of external contour which has, from its resemblance to the motions of the Amœba, been denominated the Amœba-movement (Fig. 6). It is best observed in the so-called "Amœba-form" stage of the swarm-spores of the Myxomycetes.

Fig. 6.—Outline of a plasmodium of *Didymium serpula* forming pseudopodia. The heavy black line indicates the outline at the beginning of the observation; the pseudopodium *a-b* formed in 8 seconds. *c-d* in 30, and *c-e* in 55 seconds. × 10. —After Hofmeister.

While in thinner protoplasm the streaming and mass-movements are always horizontal, or, at least, parallel with the surface upon which the plasmodium rests, in the case of tougher protoplasm they may give rise to branches which have an upward direction, as in the formation of sporangia.

9.—Effect of External Influences. The movements of the protoplasm of the Myxomycetes, and probably to a greater or less extent of all plants, are suspended by certain external influences. Violent jarring, pressure, a thrust as with the point of a pin or pencil, electrical discharges, sudden changes of the temperature, and sudden changes in the concentration of the surrounding fluid, stop the movements, and cause the plasmodium to contract into one or more spheroidal masses. When these influences cease, if they have not been so violent as to destroy the organization of the protoplasm, it returns after a greater or less length of time to its original form, and the movements are resumed.

(*a*) The effect of mechanical disturbances (jarring, pressure, and thrust) may be best studied in the tougher or least fluid plasmodia (*e.g.*, of *Stemonitis fusca*).

(*b*) The effect of electrical discharges may be studied by placing a small plasmodium (*e.g.*, *Didymium serpula*) upon a glass plate provided with platinum points which are in connection with the poles of an induction apparatus. When a discharge takes place through a narrow branch (pseudopodium) it contracts so violently as to be broken up into a row of little spheres; if it takes place through the mass of the plasmodium it becomes more or less spherical by its contraction. In any case, if the shock has not been too severe, the protoplasm after a while returns to its normal shape again.*

(*c*) The plasmodium of *Didymium serpula*, when removed from a tem-

* Kuhne performed the following curious experiment. Taking a portion of the plasmodium of *Didymium serpula*, in its resting state, he mixed it with water so as to make a pulpy or pasty mass. With this he filled a piece of the intestine of a water-beetle, and tying the ends, laid it across the electrodes of an induction apparatus. The preparation was kept in a film of water in a damp chamber for twenty-four hours, at the end of which time it was considerably distended. He now allowed the electrical current to pass through it, when it contracted itself "like a colossal muscle-fibre." Upon extending it by pulling at the ends, and then sending through it a stronger electrical current, it contracted itself one third of its length.

perature of 20° C. to one of 30° C. (68° to 86° Fahr.), withdraws its pseudopodia and ceases its activity in the space of five minutes. In an hour after the restoration of the normal temperature (20° C.) the movements begin again. If the temperature is raised to 35° C. (95° Fahr.) the organization of the plasmodium is destroyed.

The plasmodium of *Fuligo varians*, Sommf. (*Æthalium septicum*, Fr.), when placed in a chamber surrounded by ice, contracts into a rounded form and ceases all motion ; upon gradually raising the temperature again the normal state is resumed.

(*d*) In glycerine, a concentrated solution of sugar, a five per cent solution of potassium nitrate, or a five per cent solution of sodium chloride, a plasmodium contracts, and becomes rounded and motionless. A sudden decrease in the concentration of the solution by which a plasmodium is surrounded also results in a stoppage of its movements. A plasmodium of *Didymium serpula*, when placed in a one per cent solution of potassium nitrate, and allowed time to regain its activity, suddenly rounds itself up and stops its movements when the preparation is washed out with distilled water ; after the lapse of a few minutes (ten to twelve) the activity begins to show itself again, and in half an hour the normal state is restored.

10.—Ciliary Movement. The swimming of swarm-spores, spermatozoids, and many other naked protoplasmic bodies, is due to the rapid vibratory motion of extremely small whip-like extensions of the hyaline portion of the protoplasm.

Examples of ciliary movement are very common. In some swarm-spores, as in those of Vaucheria, the whole surface is covered with short cilia ; in others, as in Œdogonium, the cilia form a crown about the hyaline anterior extremity ; those of Pandorina and Cladophora, and the spermatozoids of Bryophytes and Pteridophytes, have two or more cilia ; while the swarm-spores of Myxomycetes have but one.

The rapidity of the swimming motion produced by cilia is considerable, as shown by measurements made by Hofmeister* in the case of swarm-spores, viz. :

Fuligo varians (*Æthalium septicum*)...	.7 to .9 mm. per second.
Lycogola epidendrum.................	.33 mm. " "
Œdogonium vesicatum...............	.15 to .20 mm. " "
Vaucheria sp.......................	.10 to .14 mm. " "

11.—The Activity of Protoplasm Enclosed in a Cell-wall. The movements of protoplasm in closed cells differ but little from those in naked ones ; the differences are such as are due to the fact that in the latter case the protoplasm is

* "Lehre von der Pflanzenzelle," p. 30.

free to move in any direction, while in the former its movements are greatly restricted by the surrounding walls. In closed cells there are two general kinds of movements—one a streaming, the other a mass movement—comparable to the streaming and Amœba movements of the naked cells or protoplasmic masses. No movement takes place, however (at any rate to no great extent), until the vacuoles are quite large.

12.—The streaming movements occur in the protoplasmic strings, bands, and plates which cross or separate the vacuoles, and in the lining layer of protoplasm which invests the inner surface of the cell-wall. The motion, in many cases, shows the same alternation as in the Myxomycetes, the direction of the streaming usually being reversed after the lapse of a few minutes.

The mass-movement in closed cells is not as clearly separated from the streaming as in naked cells. It usually consists in a sliding or gliding of the protoplasm upon the inner surface of the cell-wall, in much the same way as the naked plasmodium of one of the Myxomycetes moves upon the surface of its support. The limited space in which its movement must take place in closed cells, and its disposition over the whole inner surface of the wall, compel the protoplasm to move in opposite directions upon opposite sides of the cell. There is thus a kind of rotation of the protoplasm when the movement of all its parts is uniform.

(*a*) The streaming movements may be studied in the stamen-hairs of *Tradescantia Virginica*, the stinging hairs of the nettle (*Urtica*), the hairs of *Cucurbita*, *Ecbalium*, and *Solanum tuberosum*, the styles of *Zea mais*, the easily separated cells of the ripe fruit of *Symphoricarpus racemosus*, the young pollen grains of *Œnothera*, and the parenchyma of succulent monocotyledons—*e.g.*, in the flower peduncles and the filaments of *Tradescantia*. The parenchyma cells of the leaves of many trees and of the prothallia of ferns and Equisetums show a network of hyaline strings in which a streaming may with difficulty be seen.

Among the lower plants good examples may be found in the hyphæ of some Saprolegniæ, and in the cells of *Spirogyra*, *Closterium*, *Denticella*, and *Coscinodiscus*.

(*b*) In many cases (*e.g.*, in the unfertilized embryo-sac of many Phanerogams, in the young endosperm cells, and in the spore-mother-cells of *Anthoceros lævis*)—where the strings and bands resemble those in the cases cited above—no movement of the protoplasm is visible,

doubtless because of the mechanical injury of the cells in making the preparation, and the disturbing influence of the water in which it is mounted.

(*c*) In the stamen-hairs of *Tradescantia Virginica* the protoplasm

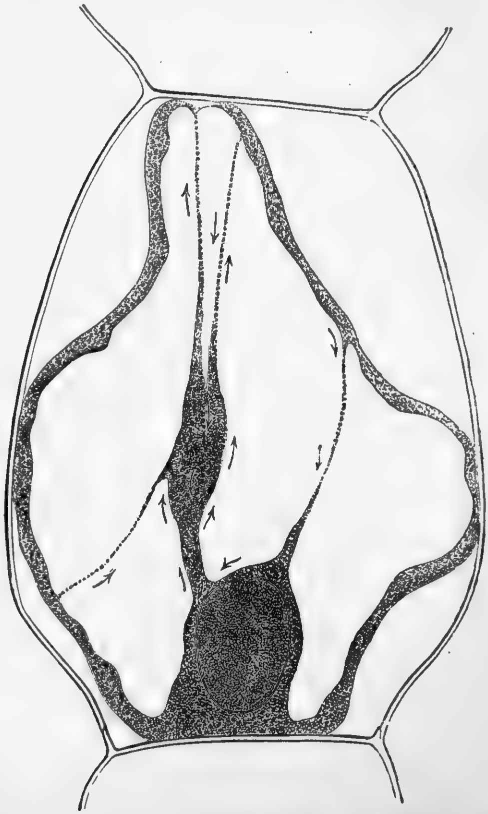


Fig. 7.—An optical section of a cell of one of the stamen-hairs of *Tradescantia Virginica*, after treatment with a solution of sugar. The protoplasmic sac has partly collapsed, on account of the withdrawal of some of the interior water by the sugar solution. At the bottom of the cell is the large nucleus ; in the strings and bands of protoplasm there are streamings of the protoplasm, shown by the arrows.—After Hofmeister.

forms a rather thick layer over the inner surface of the cell-wall, and in some part of this layer the nucleus lies imbedded. From the nucleus and from various parts of the protoplasmic layer there pass to the opposite side of the cell thicker or thinner bands and strings, always

however, more or less parallel with the longer axis of the cell (Fig. 7). In a string there may be one, two, or three currents; when there are two they are in opposite directions; when there are three the central one takes one direction and the two outer ones the other.

The strings are not stationary in the cell, but, on the contrary, they change their position with a considerable rapidity, and in a preparation soon pass out of the focus of the microscope.* By this change of place two strings may come together and fuse into one, or a string may pass to the side of the cell and become obliterated by fusing with the protoplasmic sac. New strings may be formed by a process exactly opposite to the one just described. A stream in the substance of the lining protoplasm forms a ridge projecting into the vacuole; this ridge gradually becomes higher, and finally breaks away from the protoplasmic sac, retaining its connection only at the ends. After a stream has been running in a certain direction for from ten to fifteen minutes, the motion suddenly becomes slower and soon stops entirely for from a few seconds to several minutes, and then begins to move in the opposite direction. The new movement begins and spreads as in the Myxomycetes (see paragraph 7).

(*d*) In the hairs of *Cucurbita Pepo* the arrangement of the protoplasm is much as in *Tradescantia.* The strings and bands are, however, broader, and frequently contain several currents, and the nucleus, instead of being imbedded in the lining layer of protoplasm, is in a centrally placed mass. There is a more rapid change in the form and position of the bands and strings than in *Tradescantia*, but the streaming motion is, on the contrary, considerably slower. The reversal of the streaming currents takes place in from seven to twenty minutes.

(*e*) In most cases the streams lie in the lining protoplasmic layer of the cell, or form low ridges upon its inner surface. This is the case in the hairs of the style of *Campanula*, in hyphæ (of fungi), and in the suspensor and young embryo of *Funkia cærulea.* In long cells, the movement being parallel with the longer axis, there may be, as in the pollen tube of *Zostera marina*, currents passing up one side and down the other.†

---

* This fact must be borne in mind in studying the movements of protoplasm in these cells, otherwise grave mistakes may be made. One string may move out of focus, and another, with a contrary current, may move into it, and thus a reversal of the current in the first string may erroneously be supposed to have taken place.

† To study the movements of protoplasm in pollen tubes it is usually necessary only to make a thin longitudinal slice of the stigma, and to mount and cover it in the usual way, using no water, however. After placing it under the microscope the preparation should be carefully crushed, when some of the pollen tubes may be distinctly seen. Their movements frequently continue for some hours in such preparations.

(*f*) The passage from the condition in the last examples (the so-called *circulation* of protoplasm) is an easy one to the cases where the whole mass of protoplasm moves along the cell-wall as a broad stream, passing up one side and down the other (the so-called *rotation* of protoplasm). Common and well-known examples of this kind of mass-movement occur in *Chara, Naias,* and *Vallisneria.* It may also (on the authority of Meyen) be studied in the root-hairs of many land plants—*e.g.*, of *Impatiens Balsamina, Vicia faba, Ipomœa purpurea, Cucumis, Cucurbita, Ranunculus sceleratus,* and *Marchantia polymorpha.*

NOTE.—In the study of the structures treated of in Chapters I to V inclusive, the student will do well to consult a recent laboratory manual—"Botanical Micro-Chemistry," by V. A. Poulsen (William Trelease, 1884).

CHAPTER II.

THE PLANT-CELL.

13.—In some cases plant protoplasm has no definite or constant form. This is its permanent condition in some of the lowest plants—*e.g.*, the Myxomycetes. In most other lower plants, and in all the higher ones, it has this condition only temporarily, if at all. In the great majority of cases, however, the protoplasm of which a plant is composed has a definite, and, within certain limits, a constant form. It usually appears in more or less rounded or cubical masses of minute size, and which may or may not be surrounded by a cell-wall. In this condition it constitutes the **Plant-Cell.**

The undifferentiated protoplasm of the Myxomycetes reminds us of the lower Monera among animals. In Bathybius and Protamœba the naked protoplasm of which they are composed has no constant form. In Protomyxa we have a few simple transformations which are in every respect comparable to those of the Myxomycetes.* In higher animals the protoplasm exists in minute and definitely marked masses, termed cells, or corpuscles, and these have been shown to be the exact homologues of the cells of plants.

14.—While in young cells provided with a wall the protoplasm fills the whole cavity, as in *A*, Fig. 2 (p. 3), in older ones it never does so, and generally these contain only a very small portion of it, as a thin layer covering the inner surface of the cell-wall (*B* and *C*, Fig. 2). Close examination shows that this protoplasmic sac consists of (1) a firmer hyaline layer, the ectoplasm, which is in contact with the

---

* See further on this subject in paragraph 222, Chapter XI. For a short account of these interesting animal forms mentioned above, the student is referred to Dr. Packard's "Zoology for Students and General Readers," (p. 18 *et seq.*) in the series of which the present work forms a part, and his "Life-Histories of Animals," where are also given numerous references to fuller accounts.

cell-wall; and (2) within this a less dense granular one, the endoplasm; the two layers are, however, not separated from each other by any sharp line of demarkation.*

When the endoplasm attains a considerable thickness it becomes differentiated into an external denser layer and an internal less dense one. Often one of these layers may be found to be in motion while the other is at rest.†

15.—There may almost always be seen in plant-cells bands or strings of protoplasm which lie in or between the vacuoles (Fig. 2, *B*). They are at first thickish plates which separate vacuoles, but afterward they become narrower as the vacuoles enlarge, and at last they disappear entirely. In these bands and strings, as previously stated (paragraph 12), streaming movements are frequently to be seen.

16.—Each of the protoplasm masses constituting the cells of most plants usually has a portion of its interior substance differentiated into a firmer rounded body, the nucleus Its normal position is in the centre of the cell; but it may be displaced and pushed aside by the vacuoles, so that in an optical section of the cell it may often appear to be in the margin. The nucleus is to be regarded simply as a modified part of the protoplasm of the cell, and not as something distinct from it. It may dissolve, and its substance pass into that of the remainder of the cell; afterward a nucleus may form again; and this may occur a number of times. Commonly in each nucleus one or more small rounded granules may be seen; these are called the *nucleoli*. The nucleus may form a skin (*hautschicht*) about itself, and vacuoli may be present in its interior.

17.—Cells are of very varying sizes. They differ in different plants, and also in the different parts of the same plant. In but few cases, however, are they of great size, by far the larger number being microscopic. The most striking

---

* These two layers were first described by Pringsheim in his "Theorie der Pflanzenzelle," 1854.

† Cf. Strasburger, "Studien über Protoplasma," 1876; and *Qr. Jr. Mic. Science*, 1877, pp. 124–132.

examples of large cells are found in the Thallophytes; *Nitella*, for example, has cells 50 mm. (2 inches) long, and 1 mm. (.04 inch) thick. According to Von Mohl, the bast-cells of a species of palm (*Astrocaryum*) are from 3.6 to 5.6 mm. (.13 to .21 inch) in length. For ordinary plants the average size of the cells may be given as from .1 to .02 mm. (.004 to .0008 inch). From this average size the dimensions of cells decrease to exceedingly small magnitudes. In the Yeast Plant (*Saccharomyces cerevisiæ*) the cells are about .008 mm. (.0003 inch) in diameter. The cells of *Bacterium termo* are from .0021 to .0028 mm. long and from .0028 to .0005 mm. broad (.0001–.00008 by .00008–.00002 inch).

The following table, taken from Hofmeister's "Lehre von der Pflanzenzelle," is useful as showing how the dimensions of similar cells vary in different plants:

TABLE OF DIMENSIONS OF VARIOUS KINDS OF CELLS OF WOODY PLANTS.

(In decimals of a millimetre.)

	ROBINIA PSEUDACACIA (five year-old branch).	FAGUS SYLVATICA (49-yr.-old trunk).	QUERCUS ROBUR, var. Pedunculata (five-yr.-old branch).	VIBURNUM LANTANA (four-yr.-old branch).	CINCHONA CALISAYA. (branch 2 cm. thick).	JUNIPERUS VIRGINIANUS (eight-yr.-old branch).
Cambium-cells, average length	.201	.413	.528	.339	.786	1.511
Vessel-like wood-cells, average length	.308	....	....	1.179	....	2.020
Bast-like wood-cells, average length	.301	.533	.712	....	1.819	....
Vessel-cells of the wood, average length	.205	.404	....	.615	....	....
Latticed cells of young secondary bark, average length	.212	.520	....	....	....	....
Bast-cells of young secondary bark, average length	.798	....	1.292	.403	1.152	2.183
Cells of medullary ray in the cambium ring, maximum length in tangential section	.321	.437	.178	.838	.466	.049
Do., do., maximum width in tangential section	.041	.076	.011	.017	.056	.014
Cells of medullary ray in the young wood, average length in tangential section	.376	.519	.285	.567	.630	.095
Do., do., average width in tangential section.	.043	.077	.019	.037	.075	.019
Cells of medullary ray in the young secondary bark, average length in tangential section	.342	.912	.468	.504	.744	.172
Do., do., average width in tangential section	.057	.066	031	.076	.075	.026

18.—Every free mass of protoplasm tends to assume a spherical form. The free cells of the unicellular water plants are generally more or less rounded, as are also the floating spores of most aquatic Thallophytes. In plants composed of masses of cells their mutual pressure gives them an angular outline. Where the pressure is slight the cells depart but little from the spherical shape, but as it becomes greater they assume more and more the form of bodies bounded by planes. If the diameters of the individual cells are equal and the development of the mass of cells has been uniform in every direction, we may have regular cubes, or twelve-sided bodies, *i.e.*, dodecahedra. It is rarely the case, however, that the cells have a perfectly regular form. Even when their diameters are approximately equal, they are generally so much distorted that they are best described as irregular polyhedra.

19.—It much more frequently happens that cells grow more in some directions than in others, and thus give rise to elongated and many irregular forms. In many of the Thallophytes the long filaments composing the plants are made up of elongated cylindrical cells placed end to end; while in others the cells are repeatedly and irregularly branched.

In higher plants many elongated cells occur, but here, by pressure, they generally become prismatic in cross-section.

(*a*) Many forms of cells have been enumerated, but they may all be arranged under the two principal kinds indicated above, viz., the short, and the elongated. As will be more fully shown hereafter, the various kinds of short cells constitute what is called Parenchyma; hence the cells themselves are termed Parenchymatous cells, or Parenchyma cells. Similarly, certain kinds of the elongated cells constitute Prosenchyma, and hence such are termed Prosenchymatous cells, or Prosenchyma cells. While it is impossible to draw an exact line between parenchymatous and prosenchymatous forms, yet the terms are valuable, and are in constant use to indicate the *general form*.

(*b*) Duchartre* has made an excellent classification of the prin-

---

* In his Éléments de Botanique," second edition, a large and valuable work, which the student may profitably consult.

cipal forms of cells, which is given below in a slightly modified form:

Cell short (*Parenchymatous*).	Outline smooth, or without prominences.	Cell globular or ovoid, in section round or oval	*Spheroidal.*
		Cell polyhedral.	*Polyhedral.*
		Cell a parallelopipedon, in section rectangular......	*Cuboidal.*
		Cell tabular, with an elongated rectangular section..............	*Tabular.*
	With prominences.	Cell ramose, having short and irregular projections....	*Ramose.*
		Cell star-shaped, having long projections which are more regular..	*Stellate.*
Cell elongated.		Cell cylindrical, with its ends at right angles to its axis, or but little inclined...........................	*Cylindrical.*
		Cell prismatic, with its ends at right angles to its axis, or but little inclined...........................	*Prismatic.*
		Cell fusiform [cylindrical or prismatic], with its ends oblique and pointed.........................	*Fusiform* (*Prosenchymatous*).

20.—When one or more sides of a cell are not in contact with other cells, as is the case with those cells which compose the surface of plants, the free sides are generally convex, and they often become more or less prolonged, sometimes in a curious way. The velvety appearance of the petals of many plants is due to such prolongations of the free sides of the surface cells (Fig. 8). Of a somewhat similar nature are the tubular extensions of the surface cells of young roots—the root-hairs. And here we may also place the curious star-shaped cells which project into the intercellular spaces in the interior of the stem of the water lily (Fig. 9), and those which compose the pith of certain rushes (Fig. 9*b*).

21.—In the unicellular plants each cell is an independent

organism; it absorbs nourishment, assimilates, grows, and reproduces its kind. In the higher plants, although this independence is not so evident, it still exists in a considerable degree. Here each cell is an individual in a community; but it still has a life-history of its own, a formation (genesis), growth, maturity, and death. It is the unit in the plant. Upon its changes in size, form, and structure depend the volume, shape, and structural characters of the plant and all its parts. It is thus the *Morphological Unit* of the plant.

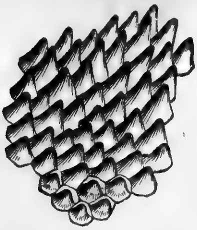


Fig. 8.—A small piece of the epidermis of the petal of a pansy (*Viola tricolor*), showing prolongations of the free (upper) sides of the cells. Mag. — After Duchartre.

22.—As the whole structure of the plant is an aggregation of cells, so the functions of the whole, or of any part of a plant are but the sum or resultant of the physiological activities of its individual cells. The cell is thus also the *Physiological Unit* of the plant.

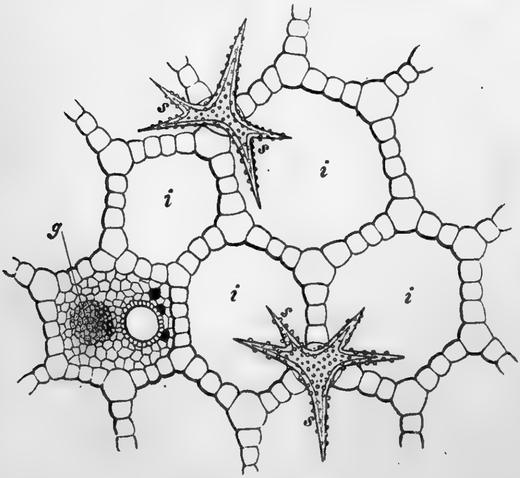


Fig. 9.

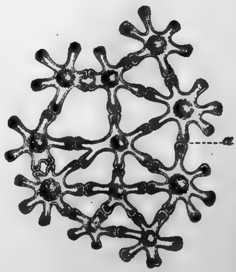


Fig. 9*b*.

Fig. 9.—A cross-section through the petiole of *Nuphar advena*; *s*, *s*, star-shaped cells projecting into the intercellular spaces *i*, *i*; *g*, a reduced fibro-vascular bundle. Magnified.—After Sachs.

Fig. 9*b*. — Stellate cells from the pith of *Juncus effusus*, magnified.—After Duchartre.

CHAPTER III.

THE CELL-WALL.

23.—In all but the lowest plants the protoplasm of every cell surrounds itself sooner or later with a covering or **wall of cellulose.** The substance of the cell-wall is a secretion from the protoplasm. Cellulose, as such, does not exist in the protoplasm ; it is formed on the surface when the wall is made. On its first appearance the wall is an extremely thin membrane, but by subsequent additions it may acquire varying degrees of thickness. The cell-wall forms a complete covering for the protoplasm ; there are at first no openings in it, at least none that are visible ; later in the life of the cell pores are formed in the wall in some cases, while quite frequently in dead cell-walls there are large perforations of various sizes and shapes.

(*a*) Cellulose is related chemically to starch and sugar. Its composition is $C_{12}\ H_{20}\ O_{10}$. It is tough and elastic. It is but slightly soluble in dilute acids and alkalies, and not at all in water and alcohol. In water, however, it swells up from imbibing some of the liquid, but it shrinks again in bulk when dried.

(*b*) *Tests.*—1. If cellulose is treated with dilute sulphuric acid, and shortly afterward with a weak solution of iodine, it is colored blue.

2. Treated with Schultz's Solution it assumes a blue color.

(*c*) In the Myxomycetes, if the large mass of protoplasm composing a plant is somewhat dried, it separates itself into smaller masses, which surround themselves with a cell-wall. Upon applying sulphuric acid and iodine, the characteristic blue color of cellulose appears, showing that the wall is a true wall of cellulose. If, however, any such dried mass of protoplasm is subjected to the proper conditions of moisture and temperature, the cell-wall is dissolved and absorbed into the protoplasmic mass. Tests applied now utterly fail to show the presence of cellulose. These observations prove the truth of the statement that cellulose is a *secretion*, and that it is not contained, *as cellulose*, in the protoplasm.

24.—After the formation of the cell-wall it generally grows, and increases its surface and thickness. Usually the surface-growth at first preponderates, afterward that in thickness. Neither the one nor the other is uniform over all points of the cell-wall, hence each cell during its growth may also change its form. As the growth of the cell-wall is directly dependent upon the protoplasm, it is clear that it can continue only as long as the protoplasm is in contact with its inner surface. In the growth of the cell-wall the new cellulose secreted by the protoplasm is deposited between the molecules of the membrane already formed. When the new molecules are deposited between the previously formed ones only in the plane of the cell-wall, surface-growth takes place; but when the planes of deposition of the new molecules lie at right angles to the plane of the cell-wall, increase in thickness is the result; when the molecules are deposited in both planes, the wall increases both in surface and thickness.

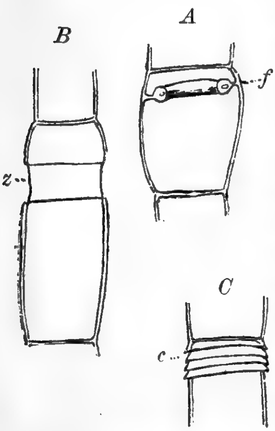


Fig. 10.—Diagrams to illustrate the intercalary growth of Œdogonium. *A*, internal ring of cellulose secreted at *f*; *B*, showing the way in which, by the horizontal splitting of the ring, the cell is elongated; *z*, the new portion of the wall formed by the splitting and extension of the ring *f* in *A*; *C*, *c*, the so-called cap, formed by several successive extensions of the cells by intercalary growth.—Modified from Sachs.

25.—**Surface-growth** may be terminal or intercalary. In the former case the growth is greatest at some point on the surface, decreasing in intensity on all sides. The growing point thus comes to project as a point or knob, or it becomes the end of a cylindrical sac. If several points of growth occur in a cell it may become star-shaped, and by a continuation of the process repeatedly branched. The typical form of intercalary growth takes place in definite belts which surround the cell, as is seen in Œdogonium (Fig. 10). The growth of the whole of the side wall of a cylindrical cell, as in Spirogyra, is also a form of intercalary growth.

26.—Growth in thickness of the wall produces changes in the cell of even greater importance than growth in surface. While surface-growth has but little to do with the determination of the functions of the cell, the thickening of its wall generally results in a change in function, or an entire suspension of all physiological activities. Cells with extremely thin walls are most active; only such can take part in growth. (See Chap. XI.) Nutrition and assimilation are confined to cells whose walls have but slight thickness. Cells with moderately thick walls may be used as storehouses for food; starch, for example, is frequently found in such cells. But as the walls attain great thickness the protoplasm loses all activity save that necessary to the secretion of cellulose.

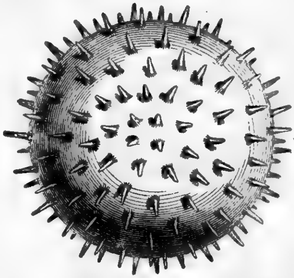


Fig. 11.—Pollen grain of *Lavatera trimestris*, covered with prickles. × 200.—After Duchartre.

27.—The thickening generally produces certain markings or sculpturings in the shape of projecting points, ridges, bands, etc., which on the one hand are on the outside of the wall, while on the other they are on the inside. In some pollen grains and spores we have the best examples of external markings. Here, in some cases, certain isolated points in the cell-wall become strongly thickened, giving rise to spines or prickles (Fig. 11). In other cases the thickening is in certain bands, which may rise into high walls, as in Fig. 12. External markings occur only upon cells which are free, or in slight contact with one another or with other cells.

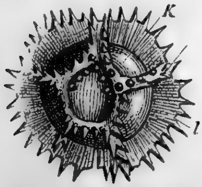
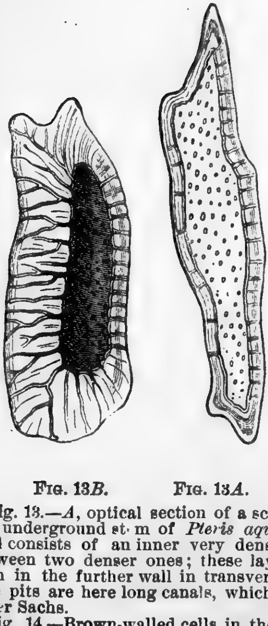


Fig. 12.—Ripe pollen grain of *Cichorium Intybus*. The almost spherical substance of the cell-wall is furnished with ridge-like thickenings united into a network. Each of these bears thickenings, which project still more, in the form of spines arranged like a comb.—After Sachs.

28.—Internal markings are of essentially the same kind as the external, although of greater variety. When the secretion of new cellulose is greatest at isolated points, knobs and projections of various kinds are the result. It more

frequently happens, however, that the thickening is in bands of greater or less width, occasionally extending over nearly the whole inner surface.

One of the simplest cases is represented in Fig. 13, where new material has been added to all parts of the wall ex-



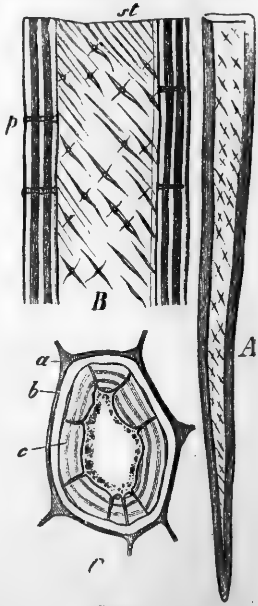


FIG. 13*B*. FIG. 13*A*. FIG. 14.

Fig. 13.—*A*, optical section of a sclerenchyma-cell from beneath the epidermis of the underground st m of *Pteris aquilina*, isolated by Schulze's maceration The wall consists of an inner very dense layer, and a central less dense one enclosed between two denser ones; these layers are penetrated by pit channels, which are seen in the further wall in transverse section. *B*, a similar cell, more thickened. The pits are here long canals, which are more or less branched. × about 550.—After Sachs.

Fig. 14.—Brown-walled cells in the stem of *Pteris aquilina*. *A*, a half cell isolated and rendered colorless by Schulze's maceration. *B*, a piece more strongly magnified (× 550). The fissure-like pits are crossed, *i.e.*, the fissure is twisted as the thickening increases; *p*, a side view of a fissure appearing as a simple channel, since it shows the narrow diameter. *C*, cross-section; *a*, boundary lamella; *b*, *c*, inner lamellæ.—After Sachs.

cepting in small isolated spots. As the wall thickens around these spots, they become at first pits, and finally channels.

29.—In some cases the pits or channels are simple, straight, or slightly bent extensions of the central cell-cavity; in others they may be branched, as shown in Fig 13*B*; in cross-section they may be round, as in Fig. 13*A*, or elon-

gated fissures, as in Fig. 14, or of any form intermediate between these. Pits with elongated fissures may be twisted, giving them, when seen in front view, the appearance of two fissures crossing one another (Fig. 14*A*, *B*).

30.—In the thickening of the cells of the wood of the Coniferæ bordered pits are formed (Fig. 15). Here large round areas of the wall remain thin, and the thickening mass arches over them on all sides in such a way as to form low domes (Fig. 16, *F*); at the top of each dome a small round opening is left, and this permits free communication between the cavity of the cell and the pits formed by the dome. This process takes place in exactly the same way upon both sides of the common wall of contiguous cells (Fig. 16, *B*, *t*, *t*, and *C*). When the partition separating opposite pits breaks away, as it generally does quite soon, the resulting cavity is doubly convex in shape (Fig. 16, *E*). When a pit of this structure is seen in front view, it has the appearance of two concentric circles (Fig. 15, *t''*, and Fig. 16, *D*); the outer one being formed by the bottom of the pit, and the inner by the opening at its top.

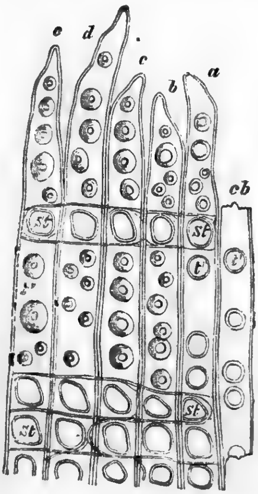


Fig. 15.—*Pinus sylvestris*; longitudinal radial section through the wood of a rapidly growing branch; *c*, *b*, cambial wood-cells (tracheïdes); *a* to *e*, older wood-cells (tracheïdes); *t'*, *t''*, *t'''*, bordered pits, increasing in age; *st*, large pits where cells of the medullary rays lie next to the wood-cells. × 325.—After Sachs.

The bordered pits of pines, firs, and other Coniferæ may be readily examined by making a longitudinal radial section. They are not found in abundance on the tangential surfaces of the cells.

The real structure of the bordered pits of the Coniferæ was not understood until quite recently.* Von Mohl, apparently not noticing the

* Schacht, in 1859 (*Botanische Zeitung*, pp. 238, 239), and in a memoir in 1860 ("De Maculis in Plantarum Vasis Cellulisque Lignosis"), gave the first correct explanation of the structure of bordered pits.

thin partition, thought that the lenticular cavity was formed by the separation of the walls of the two contiguous cells at that place, and consequently that they were *intercellular*. This interpretation is still given in some books.*

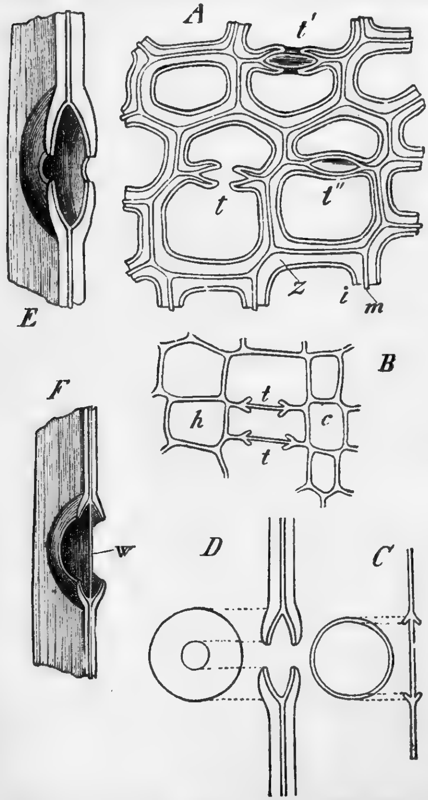


Fig. 16.—Bordered pits of *Pinus sylvestris*. *A*, transverse section of mature wood; *m*, central layer of the common wall; *t*, a mature pit cut through the middle; *t'*, the same, but in a thicker part of the section, the part of the cavity of the pit seen in perspective; *t''*, a pit cut through below its openings; *B*, transverse section through the cambium; *c*, cambium; *h*, very young wood-cells; *t*, *t*, very young bordered pits, seen in section; *C*, diagram of sectional and lateral views of a young bordered pit; *D*, diagram of sectional and lateral views of a mature bordered pit; *E*, section of a mature pit, seen in perspective; *F*, section of a younger pit seen in perspective. A and B × 800.—After Sachs.

31. — While the bordered pits of the Coniferæ are never crowded together, in the cells of some plants they are so numerous as to lie closely side by side (Fig. 17). In such case the first thickening of the wall presents itself as a network of ridges enclosing elliptical thin places. As the thickening advances the ridges increase in height, but at first not in breadth; later they increase in breadth at the top and overarch the thin areas, much as in the bordered pits of the Coniferæ. In this case, however, the opening at the top of the pit is an elongated slit instead of a circle (Fig. 17, *A*, and *C*, *c*). The thin plate separating opposite bordered pits of this kind breaks

* See Le Maout and Decaisne's "Traité Générale de Botanique," 1868 [English edition, 1872]; Griffith and Henfrey's "Micrographic Dic-

away as in the previous case, and so free communication between adjacent cells or vessels is established.

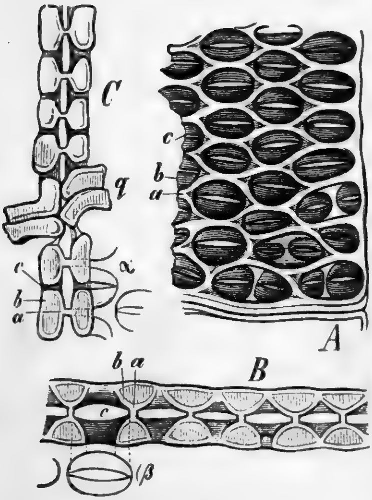


Fig. 17.

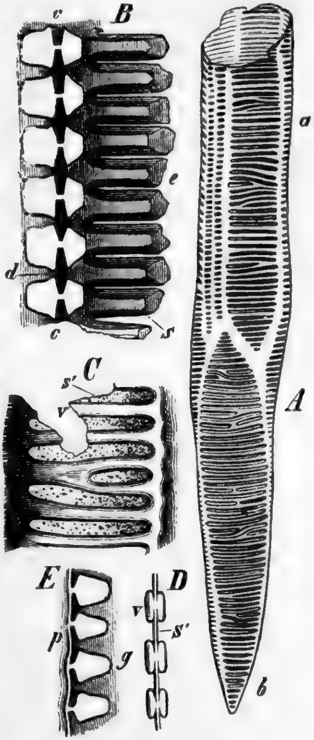


Fig. 18.

Fig. 17.—Bordered pits of the thick root of *Dahlia variabilis*. *A*, front view of a piece of the wall of a vessel, seen from without; *B*, transverse section of the same (horizontal, and at right angles to the paper); *C*, longitudinal section of *A* (vertical, and at right angles to the paper); *q*, septum; *a*, the original thin thickening-ridge; *b*, the expanded part of the thickening masses, formed later and overarching the pit; *c*, the fissure through which the cavity of the pit communicates with the cell cavity; at α and β the corresponding front view is appended, in order to make the transverse and longitudinal sections more clear. × 800.—After Sachs.

Fig. 18.—Scalariform thickening of the walls of a vessel from the underground stem of *Pteris aquilina*. *A*, half-vessel, isolated by Schulze's maceration; *B* to *D*, pieces obtained from stems hardened in absolute alcohol; *B*, a partly diagrammatic view of a vertical section of the wall, seen from within; *c*, *c*, plan of section; *d*, opening to pit; *C*, front view of young wall of a vessel; *s*, unthickened portion of wall; *v*, thickening-ridge; *D*, vertical section of *C*; *E*, section of wall in a place where a vessel adjoins a succulent cell *p*; the thickening-ridges (*g*) are only on one side. × 800.—After Sachs.

---

tionary," third edition, 1874; Carpenter's "The Microscope," fifth edition, 1874.

32.—The passage from the mode of thickening just described to the scalariform manner (Fig. 18) is an easy one. Here each longitudinal angle of the cell or vessel is thickened, and from these thickened angles ridges run right and left, from one to the other (Fig. 18, *C*, *v*). The after growth of the ridges is essentially the same as in the case of crowded pits; in fact, the pits here are simply greatly elongated and crowded bordered pits. Eventually the narrow plates between the thickened ridges disappear, as in the other cases. Examples of scalariform thickening are common, especially in the ferns.

33.—The development of rings (Fig. 19, *v*) is nearly like that of the scalariform thickening. Instead, however, of

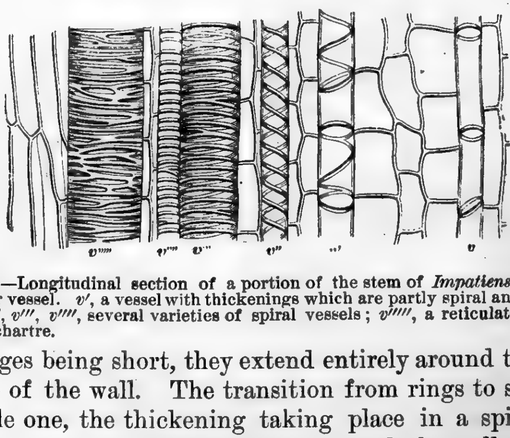


Fig. 19.—Longitudinal section of a portion of the stem of *Impatiens Balsamina*. *v*, annular vessel. v', a vessel with thickenings which are partly spiral and partly annular; v'', v''', v'''', several varieties of spiral vessels; v''''', a reticulated vessel.—After Duchartre.

the ridges being short, they extend entirely around the inner surface of the wall. The transition from rings to spirals is a simple one, the thickening taking place in a spiral line, instead of in one passing directly around the wall (Fig. 19, v'', v'''). Transitional forms are frequently found (Fig. 19, v'), and many modifications and irregularities occur—*e.g.*, in the figure at v''''' is the form known as the reticulated.

34.—In all the foregoing cases the marking of the wall has been general; there are some cases, however, where it is localized. A good example of this is in the formation of the pits of sieve-cells (Fig. 20). The horizontal walls, and also areas upon the longitudinal ones, become thickened reticulately, leaving rather large thin areas, as shown in Fig. 20, *q*, *q*. After a while the thin areas become absorbed,

allowing the protoplasm of contiguous cells to become structurally united. The sieve-like appearance of these modified portions of the wall give to the cells their name of sieve-cells.

35.—The collenchyma cells which are frequently found beneath the epidermis of the succulent parts of higher plants afford another instance of localized thickening. Here only the angles of the cells become thickened, leaving broad portions of the wall unmodified (Fig. 21).

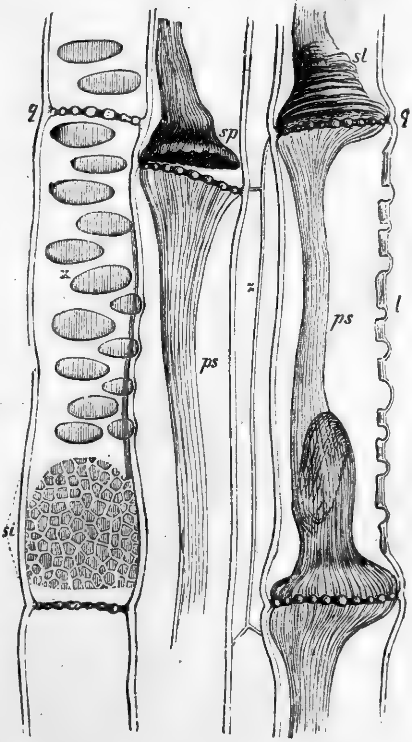


Fig. 20.—Young sieve tubes of *Cucurbita pepo* The drawing made from specimens which, by having lain a long time in absolute alcohol, have allowed the production of extremely clear sections ; *q*, transverse view of sieve-like septa ; *si*, sieve plate on side wall ; *x*, thinner parts of the longitudinal wall ; *l*, the same seen in section ; *ps*, contracted protoplasmic contents (lifted off at *sp* from the transverse septum, still in contact at *sl*) ; *z*, parenchyma-cells between sieve-tubes. × 550. —After Sachs.

(*a*) Examples of the uniform thickening of the cell-wall may be obtained for study by making thin sections of the hard parts of many nuts and seeds (Figs. 58 to 61); in many of these more or less complex channels may be found. Bordered pits are best studied in longitudinal sections of the young wood of the pines, firs, etc., and the crowded pits in the stems of most other Phanerogams. Longitudinal sections of the stems of most annuals will yield good examples of ringed, spiral, and reticulated thickening. The stems of the Cucurbitaceæ (Pumpkin, Squash, Gourd, etc.) furnish fine examples of sieve cells and collenchyma.

(*b*) In this place may be mentioned the curious and sometimes puz-

zling hernioid protrusions to be met with in some plants. When the surrounding cells are very active, it sometimes happens that the thin membrane which closes up a pit grows and is pushed through into

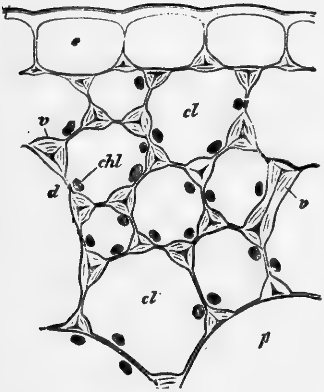
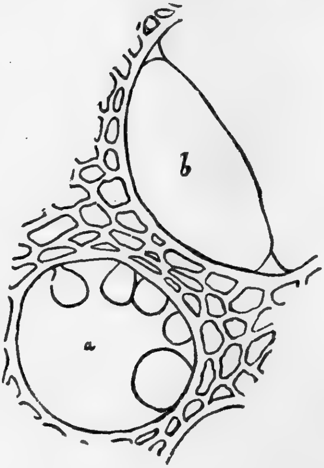


FIG. 21.



the vessel, as at *t* in the lower figure (Fig. 21*a*), where *th* represents the thickened portion of the wall, and *wa* the thin portion closing the pits. Occasionally many such protrusions enter the vessel, as in *a* in the upper figure; if these become large they may entirely fill up the cavity of the vessel, as at *b*, where two large ones from opposite sides have met.

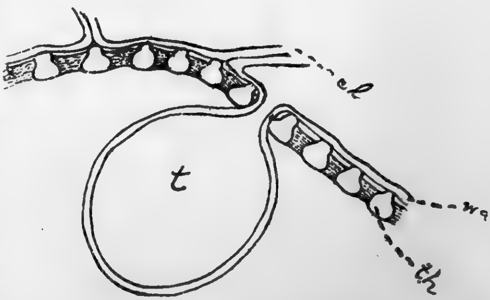


FIG. 21*a*.

Fig. 21.—Collenchyma cells of the Begonia, transverse section of the petiole. *e*, epidermis; *cl*, collenchyma-cells, with thickened angles, *v*, *v*; *chl*, chlorophyll-bodies; *p*, large cell of parenchyma. × 550.—After Sachs.

Fig. 21*a*.—Hernioid protrusions into the pitted vessels of *Echinocystis lobata*; the upper figure magnified 250, and the lower 1000.—From drawings by J. C. Arthur.

36.—Theories as to the Mode of Thickening. The real nature of the process in the growth in surface and thickness

of the cell-wall was for a long time not fully understood. There have been three prominent theories advanced to explain the phenomena observed. They may be briefly stated as follows:

I. Von Mohl held that "the growth of the cell-membrane in thickness arises from a periodical apposition of new membranes upon the already completely developed wall." * According to this theory, the marks of stratification usually seen were supposed to be the lines separating the added membranes. This deposition was supposed to proceed from without inwards; that is, the newer layers were supposed to be placed inside of the previously existing ones; on this account this has been called the theory of *centripetal* thickening. Until quite recently this has been the prevailing theory in English and American books.

II. Some observers, among whom were Hartig and Harting, laying great stress upon the external markings, as seen in pollen grains, spores, etc., opposed the foregoing theory, and propounded one which has been termed the theory of *centrifugal* thickening. According to this theory, "the cell-membrane increases in thickness in the direction from within outwards by the deposition of layers upon the outside of the original membrane." It is thus the exact opposite of the previous one; while in the former the outer membrane is supposed to be the oldest, in the latter it is the inner one.

III. The theory which now generally prevails is that the thickening of the wall is a growth, due to the formation or deposition of new molecules between the molecules of the original membrane. It is called the theory of *intussusception*, and was originated by Nägeli in 1858.†

*** The student will find a condensed statement of this theory in the "Principles of the Anatomy and Physiology of the Vegetable Cell," by Hugo Von Mohl, translated by Henfrey, 1851.**

† Nägeli, "Die Stärkekörner," in "Pflanzenphysiologischen Untersuchungen," 1858. Duchartre claims for Trecul the first suggestion of this theory in 1854. The term intussusception as applied to the growth of the cell-wall was used long before this; Schleiden, in his "Contri-

37.—Every part of the living cell-wall appears, from the results of Nägeli's researches, to be composed of definite molecules, which are not in contact, but separated from one another by layers of water, termed the Water of Organization. The thickness of these intermolecular layers, and consequently the amount of water in the whole mass of any cell-wall, varies in different cells, and even in the same cell. In the denser walls, or parts of walls, the water is less; in those which are less dense it is greater. (Fig. 22.)

Now it is evident that young cell-walls must have relatively large amounts of water in their substance, and here is where we find a growth taking place. Sachs supposes* that an aqueous solution derived from the protoplasm penetrates by diffusion between the molecules of the cell-wall. This is not a solution of protoplasm, but probably some carbohydrate constituent of the protoplasm which is easily transformed into cellulose. From this nutrient solution there may be formed in the spaces filled with water new molecules of cellulose, which push aside and separate the previously formed ones; or the previously formed molecules may be simply enlarged by the apposition of new matter.

According to the theory just described, the formation of any projection upon the inner surface of the cell-wall is not by the superficial deposition of molecules upon any definite area of the surface of the wall, but by the abundant and continued deposition of new molecules *in* the wall; it consequently becomes thicker at the place of deposition; in this thickened portion still more molecules are deposited, and the thickness is further increased, and so on. In the same way projections are formed upon the outside of the wall by a slow internal growth.

38.—Stratification of the Wall. During the increase of the cell-wall in thickness, an appearance of stratification arises in it (Fig. 23). A cell-wall in which this is strongly developed appears to be made up of concentric layers, and this no doubt gave rise to the two theories before men-

---

butions to Phytogenesis," 1838, makes use of the word, but it may be doubted whether he or Trecul gave it exactly the meaning we now do.

* "Lehrbuch," fourth edition, and the English translation of the third edition (" Text-Book of Botany "), Books I. and III.

tioned, in which the thickening was supposed to be due to the successive deposition of layers, either inside or outside of the original wall. It is now known that stratification is due to a subsequent change in the amount of water of organization present in particular parts of the wall. When seen with the microscope, those layers which contain the most water, and consequently the least cellulose, are less strongly refractive than those which contain less water, or which, in other words, are denser.

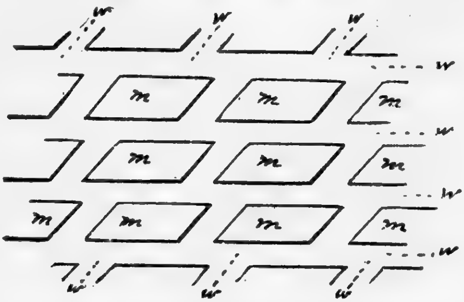


Fig. 22.—Diagrammatic figure to illustrate Nägeli's theory of the molecular structure of the cell-wall; *m, m, m*, the crystal molecules; *w, w, w*, the layers of water which separate the molecules. The water layers are represented as very thin; they are frequently much thicker in proportion to the diameters of the molecules. (NOTE.—It must be borne in mind that this figure is purely diagrammatic.)

39. Striation.—In many cases there is also a similar separation into more watery and less watery layers at right angles to those just mentioned. There may be one system of such differentiation, giving rise to a transverse striation, which may be annular (Fig. 24, *c, d, e*) or spiral (*a, b*); or there may be two systems, and then the wall appears to be crossed by two sets of spirals which run in opposite directions around the cell.

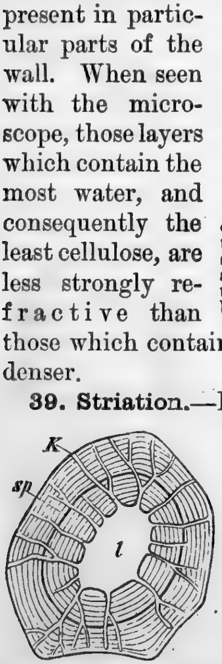


Fig. 23.—Transverse section of a bast fibre of the thickened root of *Dahlia variabilis*; *l*, the cavity; *K*, pit channels which penetrate the stratification; *sp*, a crack by which an inner system of layers has become separated. × 800. —After Sachs.

Good examples of stratification may be found in the pith-cells of the root of the dahlia, and in the epidermal cells of most thick leaves; and of striation in the bast-cells of the periwinkle (*Vinca major*), and the wood of the Douglas Spruce (*Tsuga Douglasii*). In many cases it is necessary to treat the specimens with such acids (*e.g.*, sulphuric acid) or alkalies (*e.g.*, caustic potash) as will produce swelling.

40.—Formation of Chemically Different Layers. A still further differentiation may take place in the thickened wall, by which it comes to be made up of layers which differ chemically from one another. This is brought about by the subsequent infiltration of diverse materials into different layers. In some cases the chemical change is accompanied by so great a physical change that the wall separates readily into two or more plates.* Thus, in pollen-cells, the original wall is usually differentiated into two widely differing plates: (1) an outer thick cuticularized covering (the extine), and (2) a thin inner membrane (the intine); the inner plate is shown by tests to be composed of pure cellulose, while the outer one is generally so filled with other materials as to hide completely the cellulose.

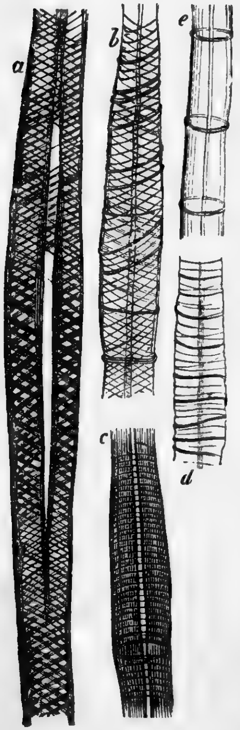


Fig. 24.—Striation of the bast fibres of *Hoya carnosa*; *a* and *b*, crossed annular striation; *c*, *d*, *e*, varieties of simple annular striation.—After Sachs.

A similar differentiation of the wall takes place in certain spores, and in such case the outer plate is called the exospore (or epispore), and the inner one the endospore (see *C, D, E, F*, Fig. 180, p. 262).

The outer walls of the epidermal cells of many plants show a remarkable separation into one or more plates, the outermost of which is highly cuticularized. In some cases, as in the cabbage, for example, this outer plate may easily be separated as a continuous pellicle—the so-called cuticle.

Wood-cells frequently show a well-marked separation into plates. This may be seen in *Pinus sylvestris* (Fig. 16, p. 26), where there are three such

---

* These are the "Schalen" of Sachs, translated "Shells" in the English edition of his "Lehrbuch."

plates, viz., a thin inner one (i), a thicker middle one (z), and a thin outer one (m). The latter is apparently common to the two contiguous cells, and is the "primary cell-wall" of some authors and the "intercellular substance" of others.

The deportment of these layers on the application of reagents is interesting.

1. On treatment with a solution of iodine the outer and middle plates turn yellow.

2. On treatment with iodine and sulphuric acid the outer and middle plates turn yellow and the inner one blue.

3. On treatment with concentrated sulphuric acid the inner and middle plates are dissolved, while the outer remains.

4. On boiling in nitric acid with potassium chlorate the outer plate is dissolved, while the middle and inner are not. By this latter process, called "Schulze's Maceration," the cells may be isolated, but it must be borne in mind that such isolated cells have lost by solution their outer plate.

41.—In some cases the differentiation is of such a nature that one or more plates become converted into mucilage in water. In the dry state the mucilaginous portions are hard and cartilaginous. Examples of the change of the outer plates into mucilage are common in the Fucaceæ, and of a similar change of the inner ones in the seeds of flax and quince.*

42.—Incombustible Substances, as silica and lime, are frequently deposited between the molecules of cellulose in the wall. Cell-walls which are filled with considerable quantities of these substances, upon burning, leave ash-skeletons, which retain the form and markings of the cell. The Diatoms furnish excellent examples of highly silicified walls. Silica is abundant also in the epidermal cells of grasses and scouring-rushes (*Equisetaceæ*).

Lime-skeletons may be obtained by the combustion of thin slices of the tissues of many plants upon glass or platinum-foil. The vessels of *Cucurbita Pepo* yield (according to Sachs) beautiful skeletons under this treatment.

Silica-skeletons may be obtained by first soaking the tissue in nitric or hydrochloric acid and then burning, or by burning (upon platinum-foil) in a drop of sulphuric acid.

---

* Sachs attempts to reduce the chemical differentiations of the cell-wall to three categories, viz., Cuticularizing, Lignification, and Conversion into Mucilage.

CHAPTER IV.

THE FORMATION OF NEW CELLS.

43.—There are two essentially different ways in which cells originate, viz., (1) by the division of a protoplasmic body into two or more bodies; (2) by the union of two or more protoplasmic bodies.

44.—Cell-Formation by Division. The simplest cases of the formation of cells by division occur in the Myxomycetes. The swarm-spores (*a*, Fig 25), which are naked masses of freely moving protoplasm, first lose their nuclei (as in *b*), and then become constricted (as at *c*); the constriction deepens, and finally divides each mass into two parts (*d*, *e*, *f*).

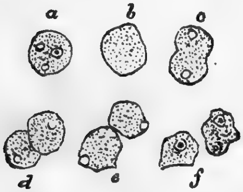


Fig. 25.—Division of the swarm-spores of *Chondrioderma difforme*; *a*, with nucleus; *b*, nucleus dissolved; *c*, two nuclei, division of protoplasm begun; *d*, *e*, *f*, completion of the process.—After De Bary.

45.—This may be taken as the type of cell-formation by division, and in no case does it differ in any essential particular from this. Most plant-cells, however, are surrounded by a wall, whose deportment during division enables us to distinguish two more or less well-marked modes of cell-formation by division. On the one hand the wall divides as well as the protoplasm (*Fission*), while on the other the wall takes no part in the division, and it is only the protoplasm which divides (*Internal Cell-Formation*).

46.—The best examples of Fission are to be seen in those unicellular plants which have been frequently described under the name of *Protococcus*.* "The cell elongates and the protoplasm divides into two across its longer axis, and

---

* See "Huxley and Martin's Biology," Chap. II.

then a partition is formed subdividing the sac; the halves either separate at once and each rounds itself off and becomes an independent cell, or one or both halves again divide in a similar way before they separate, and so three or four new cells are produced."

47.—In many of the filamentous Thallophytes a similar fission takes place, but in these the cells do not immediately separate from one another after their formation. Thus, in *Nostoc* and *Oscillatoria* (Fig. 26) the cells do not differ in any essential way as to their formation from those which constitute *Protococcus.* In *Nostoc* after fission the cells round themselves up and retain but a slight and easily separable connection with one another; in *Oscillatoria,* on the contrary, the cells remain cylindrical and are less readily separable.

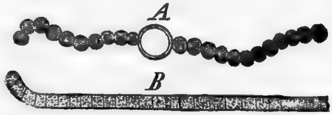


Fig. 26.—*A*, filament of *Nostoc; B*, filament of *Oscillatoria.* × 300.—After Prantl.

48.—In *Spirogyra* (Fig. 36, p. 45) new cells form by the partition of old ones. The protoplasmic sac infolds all around the middle of the old cell which is cylindrical in shape; into the circular channel thus formed the cell-wall extends, appearing at first as a narrow projection from the original wall, but becoming broader and broader, until it forms a complete partition. When the new cells have elongated by intercalary growth the process of fission may be repeated, and so on.*

49.—The cells which make up the greater part of the tissues of the higher plants are formed by fission. In the apical cells of *Equisetum* we find a curious regularity in the

---

* The student is referred to Sachs' "Text-Book," pp. 17–18, for a further description of this process in *Spirogyra;* and to Von Mohl's "Anatomy and Physiology of the Vegetable Cell," pp. 50–51, for a description of the similar fission of *Cladophora glomerata* (*Conferva glomerata,* Linn.). Von Mohl's description, which was the result of the first accurate investigation of cell-formation, is erroneous in this—that he supposes that during the process, to quote his words, "a cellulose membrane is deposited all over the outside of the primordial utricle" of the whole cell, and that it is a portion of this new membrane which forms the partition.

division. The triangular apical cells of the growing stems divide repeatedly in the manner shown in the diagram (Fig. 27). Here the cell *A B C*, bounded by the heavy black

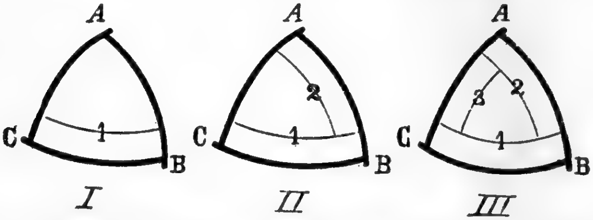


Fig. 27.—Diagram to show mode of fission of the apical cell, as seen from above. *I*, the cell *A*, *B*, *C*, divided by the partition 1; *II*, the same cell with a second partition, 2; *III*, the same cell with a third partition, 3.

lines, is first divided into two unequal portions by the partition 1, I.; next the larger portion of the divided cell is again divided by the partition 2, II.; later, a third partition (3, III.) is formed, and so on. It is noticeable that in this case the partition always forms parallel to the oldest wall of the dividing cell. By continued growth the apical cell retains, despite its repeated divisions, its original dimensions.

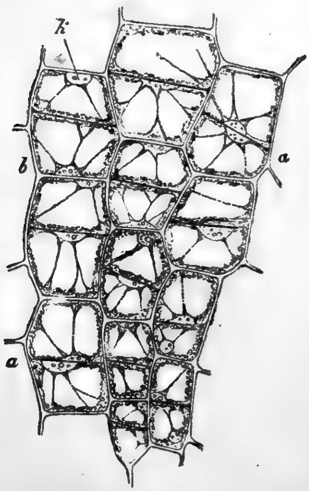


Fig. 28.—Meristem-cells of the stem of *Vicia faba*, in process of fission; in the cells *a*, *a*, the process is in its earlier stage; at *b* it is completed. × 300.—After Prantl.

50.—The growing cells of the stem of the English bean (*Vicia faba*) furnish a good illustration of fission in the highest plants. In this case, and in many other, if not all, Dicotyledons, the division takes place directly through the centrally placed nucleus (*a*, Fig. 28). After the formation of the new wall each new nucleus moves away and occupies a position on the opposite side of the cell from where it was formed (as at *b* and *k*).

(*a*) The foregoing must suffice as examples of Fission. It occurs throughout the vegetable kingdom and may be regarded as the great means by which cells are multiplied.

(*b*) The cambium zone of Dicotyledons may be examined very profitably by the student. If a thin cross-section of a stem be soaked for a short time in a carmine solution, the protoplasm of the cambium zone will be colored, and the newly formed partitions made thus more distinct.

(*c*) The ends of young roots are valuable for study; longitudinal sections of these should be made, and treated as in the previous case.

(*d*) Another interesting study of a special kind of fission may be taken up in an examination of the development of stomata. (See p. 99.)

(*e*) That slight variation of fission, which has sometimes been called budding, may be very easily studied in the Yeast Plant (*Saccharomyces cerevisiæ*).* The conidia, stylospores, and basidiospores of many fungi, which are more difficult to study, are very instructive examples of this variety of fission. Conidia may be studied in *Cystopus;* stylospores in the Red Rust of the grasses (the so-called uredo-stage of *Puccinia graminis*); and basidiospores in young toadstools (*Agaricus*).

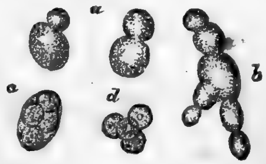


Fig. 29.—The Yeast Plant, *Saccharomyces cerevisiæ*. *a*, rounded cells from "bottom yeast," 50 hours after sowing in beer-wort; *b*, row of oval cells from "top yeast;" *c*, bottom yeast after cultivation on a piece of carrot, four cells forming in the interior of the parent cell; *d*. the four daughter-cells; *a* and *b* × 400, *c* and *d* × 750.—After Reess.

51.—The Yeast Plant (*Saccharomyces cerevisiæ*) furnishes a very simple example of Internal Cell-Formation. Under certain conditions the cells grow to a larger size than usual; their protoplasmic contents divide into, generally, four parts (two to four, according to Sachs), each of which rounds itself up and secretes a wall of cellulose on its surface (Fig. 29, *c, d*). Cells which divide in this way are called mother-cells, and the new ones formed from them daughter-cells. In the Yeast Plant after the daughter-cells are fully formed the dead wall of the mother-cell breaks up.

52.—The terminal cells of *Achlya* (one of the *Saprolegniaceæ*) form large numbers of daughter-cells by the breaking up of the protoplasm, as shown in Fig. 30, *A*. When the daughter-cells escape they become rounded (*B,a*);

* See "Huxley and Martin's Biology," Chap. I.

after a little while they break their cellulose walls and become naked motile cells (zoospores) (*B*, *e*).

53.—As the formation of the spores of Bryophytes and Pteridophytes, and of the pollen-cells in Phanerogams, is essentially alike, we may take as an example the formation of the spores of a fern (Fig. 31). The nucleus of the mother-cell first disappears, and two new nuclei arise (I., II., III.); between the nuclei may be seen a line indicating the separation of the protoplasmic mass into two halves. Next the nucleus in each half is absorbed and replaced by two, between which a separation of the protoplasm soon takes place (IV., V.), thus dividing the cell into four equal parts, which are at first angular, but soon rounded and enclosed in cell-walls (VI., VII., VIII., IX.).

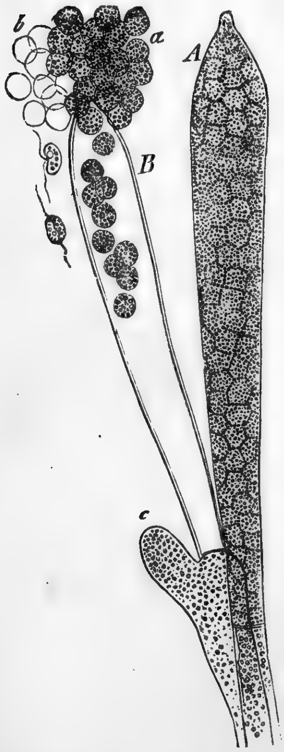


Fig. 30.—Terminal cells of *Achlya*. *A*, still closed, but with the protoplasm in process of division; *B*, the daughter-cells escaping through a rent in the wall of the mother-cell; at *a* the daughter-cells have just escaped; *b*, the thin cellulose walls of the daughter-cells, from which the contents have escaped as motile cells (zoospores), *e*; *c*, a young lateral branch. × 550.—After Sachs.

54.—In the foregoing cases the whole of the protoplasm of the mother-cell is used in the formation of the daughter-cells. There are some cases, however, in which only a part of the protoplasm is used. One of the best known is in the formation of ascospores. Here the mother-cells are usually large and elongated (Fig. 32, *a*, *b*, *c*); the nucleus disappears, and the protoplasm condenses in the upper portion of the mother-cell; in some cases (not in the species figured) nuclei appear, and about these portions of the protoplasm gather to form the ascospores; in other cases (Fig. 32) the protoplasm condenses

about certain points without the previous formation of nuclei (*d, e*). In either case firm walls are secreted about the spores while yet in the mother-cell and surrounded by the unused part of its protoplasm.

55.—The most striking example of this variety of internal cell-formation is to be found in the development of the endosperm cells in the embryo sac of Phanerogams. The protoplasm which occupies the cavity of the embryo sac presents here and there points of condensation or concentration, which in a little time become as many nuclei (Fig. 33, *A, n, n*), each containing a nucleolus. These nuclei are the first indications of the forming cells. Protoplasm gathers about the nuclei and forms globular or ovoid masses (*A, a, a*), which, after acquiring a certain size, secrete a thin wall of cellulose on their surfaces (*A, c, c′, d*). By the continued production of new cells within the embryo sac, in this way, they finally become crowded together into a loose tissue, in whose intercellular spaces portions of the unconsumed protoplasm yet remain (*B*). After their formation the cells go on increasing in numbers by simple fission (*B, a, b*).*

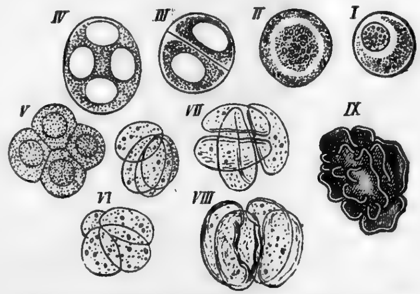


Fig. 31.—Development of the spores of *Aspidium filix-mas*. *I*, the spore-mother-cell, with nucleus; *II*, the nucleus absorbed; *III*, two nuclei, and the division of the protoplasm into two portions; *IV*, four nuclei; *V*, division of the protoplasm into four portions; *VI, VII, VIII*, rounding up of the young spores during the secretion of their cell-walls; *IX*, mature spore, with thick and sculptured exospore (epispore). × 550.—After Sachs.

(*a*) Sachs † makes a strong distinction between the cases of internal cell-formation where, on the one hand, a *part* only, and, on the other,

---

* The student is here referred to the account of the formation of endosperm cells in Duchartre's "Éléments de Botanique," pp. 37–39; and also to Hofmeister's "Lehre von der Pflanzenzelle," Section 17.

† "Lehrbuch," 4te auf. In the English translation of the third edition all cases of fission are included under the Formation of Cells by Division of the Mother-Cell.

the *whole* of the protoplasm of the mother-cell is used. The former he calls *Free-Cell Formation*, and the latter *Formation of Cells by Division of the Mother-Cell*, and includes also under the last a part of what has been described above under the head of Fission. It is doubtful, however, whether such a division is of much importance.

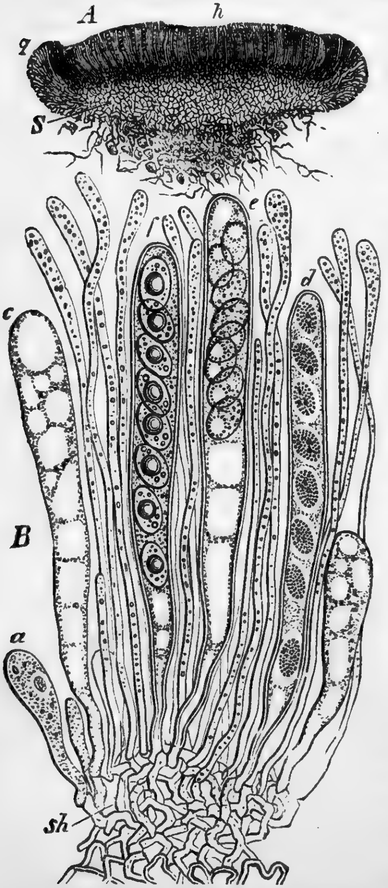


Fig. 32.—*Peziza convexula*. *A*, vertical section of the whole plant; *h*, hymenium—*i.e.*, the layer in which the spore-forming sacs lie , *S*, the tissue of the fungus enveloping the hymenium at its edge *q* in a cup like manner ; at the base of the tissue *S* fine threads arise, which grow between the particles of earth. *B*, a small portion of the hymenium; *sh*, sub-hymenial layer of densely interwoven filaments (hyphæ) ; *a* to *f*, spore-forming sacs (*asci*), with thin filaments (paraphyses) between them. $A \times 20$, $B \times 550$.—After Sachs.

(*b*) What has been called the Rejuvenescence of a cell may be mentioned here. The phenomena connected with it are as follows: The protoplasm of a cell contracts, expels a portion of the water contained in it, and escapes through a slit in its wall ; the naked mass becomes for a time a free-swimming zoospore, after which it secretes a wall of cellulose, and begins to grow and form new cells by fission. Cases of this kind occur in *Œdogonium*, Stigeoclonium, and many other aquatic Thallophytes. An interesting fact, but probably of no great significance, is that the axis of growth of the new cell is perpendicular to that of the old one.

While there can be no doubt that this process, as Sachs insists,* "must be regarded morphologically as the formation of a new cell," there can be little question that it is closely related to the formation of zoospores described above (p. 40). The difference is that in the formation of ordinary zoospores the mother-cell breaks up into more than

* See "Text-Book," p. 9, and also "Lehrbuch," 4te Auf., where the author sets apart this as an entirely different mode of cell-formation.

one mass before escaping; while in Rejuvenescence the whole protoplasm escapes without dividing. Rejuvenescence may then be regarded

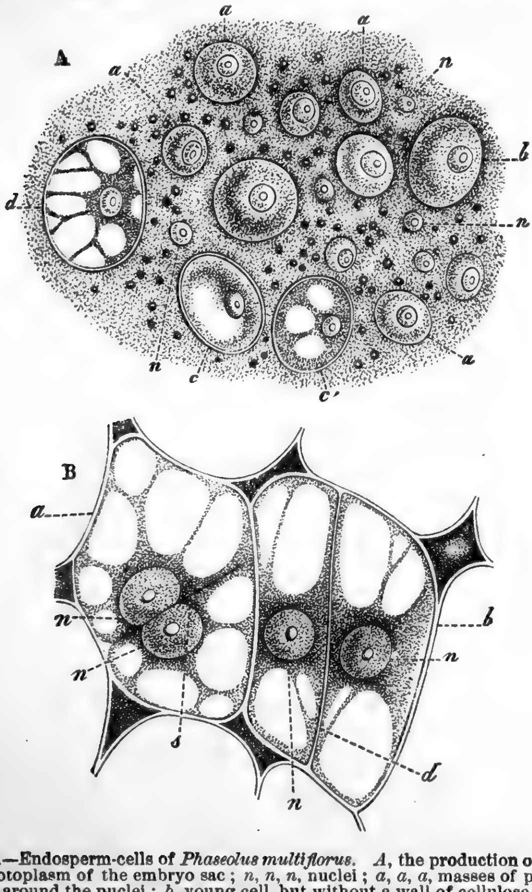


Fig. 33.—Endosperm-cells of *Phaseolus multiflorus*. *A*, the production of new cells in the protoplasm of the embryo sac; *n*, *n*, *n*, nuclei; *a*, *a*, *a*, masses of protoplasm gathered around the nuclei; *b*, young cell, but without a wall of cellulose; *c*, young cell with a wall; *c'*, *d*, young cells with walls and vacuoles. *B*, two cells of the endosperm in a much later stage; the cells have fused their walls so as to form a false tissue; in the angles between the cells are intercellular spaces filled with some of the protoplasm of the mother-cell (embryo sac); the cell *a* is in process of fission, the two nuclei *n*, *n*, are near together, as if formed by the fission of the original nucleus; *s*, line indicating the boundaries of the two masses of protoplasm; the cell *b* is fully divided, and the two parts are separated by the wall *cl*. × 670.—After Dippel.

as a case of internal cell-formation in which there is no division of the protoplasm.

56.—Cell-Formation by Union. The simplest example of cell-formation by the union of cells is found in the Myxomycetes. The swarm-spores which have been described as multiplying by division (see p. 36) somewhat later begin the opposite process of uniting. Two or more approach one another and gradually coalesce into a homogeneous protoplasmic mass (Fig. 34). During the process the nuclei disappear. The union, at first sight, appears to be no more than a mere running together of similar drops; but the disappearance of the nuclei shows that, however much it may resemble such a purely physical process, the coalescing of the swarm-spores of the Myxomycetes is something more. It is possible that there is also some very slight difference between the uniting cells.

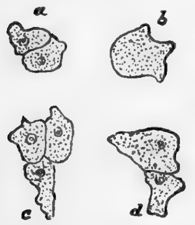


Fig. 34.—Union (the so-called conjugation) of the swarm-spores of *Chondrioderma difforme*, Pers. (*Didymium Libertianum* of De Bary); *a*, two swarm-spores; *b*, the same fused into one; *c*, three swarm-spores; *d*, the same a few moments afterward, the two upper ones fused into one. × 390.—After Cienkowski.

57.—In *Cosmarium*, a genus of the Desmidiaceæ, the uniting cells have well-developed walls, and as a consequence the process is somewhat different from what it is in the Myxomycetes. The cells, which in this genus are two-lobed (Fig. 35), approach each other; each sends out from its centre a protuberance which meets the other (*d*); the thin walls separating the cavities of the protuberances are absorbed, and the united protoplasmic masses form a round ball (*e*), which soon becomes enclosed in its own proper coatings (*f*).

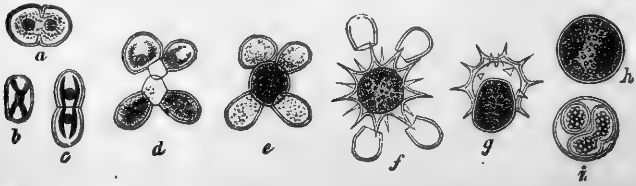


Fig. 35.—*Cosmarium Meneghinii.* *a*, *b*, *c*, different views of the mature plants; *d*, *e*, and *f*, three stages in the formation of the new cell; *g*, *h*, and *i*, the after-development of the new cell. × 475.—After Œrsted.

58.—The union of cells in *Spirogyra* is much like that of *Cosmarium*. Here the cells are united into long filaments,

instead of being independent, as in the previous case. At the time of union the filaments approach one another and lie nearly parallel; protuberances grow out from the contiguous cells (Fig. 36, *a*, *b*); their extremities meet, and the walls are absorbed, making a channel of communication from cell to cell (Fig. 36). Through this channel the protoplasm from one of the cells passes into the cavity of the other; the two masses unite and form a round or ovoid cell, which soon secretes a wall of cellulose (Fig. 37, *A*, *b*, and *B*, *c*).

The particular kind of union in which the two cells are of equal or nearly equal size, and illustrated above by *Cosmarium* and *Spirogyra*, has received the name of Conjugation. It is characteristic of one group of the Thallophytes, viz., the *Zygosporeæ*.

59.—In *Vaucheria*, a fresh-water Thallophyte, we have an example of the union of cells of very different sizes. The larger cells (called *oospheres*) are in lateral protuberances of the large single cell which composes the whole plant (Fig. 38, *A*, and *B*, *og*). The protoplasm in these is of a spherical form, and is much denser than in the main cell, from which it is separated in each case by a transverse wall (shown in *F*). The smaller cells (the *spermatozoids*) are produced by the internal cell-division of the protoplasm of similar protuberances (the antheridia, *A*, and *B*, *a*). They are very small as compared with the oospheres, and are naked masses of protoplasm provided with two cilia, by means of which they are locomotive (*D*). Upon escaping into the water by the bursting of the old wall, they swim about, and

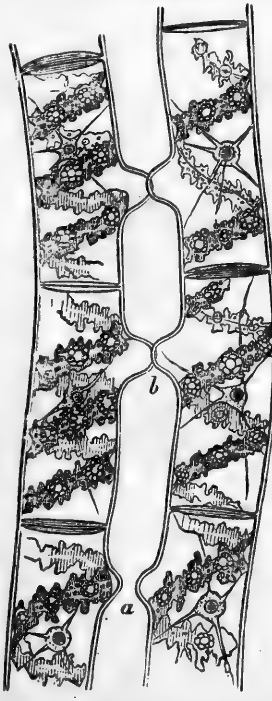


Fig. 36.—Two filaments of *Spirogyra longata* about to conjugate; at *a* and *b* are seen the protuberances from the contiguous cells approaching each other. × 550.—After Sachs.

some of them finally reach the oosphere (through a rupture in its wall), and unite with its protoplasm (*E*, *F*). The result is at once seen in its greater sharpness of outline, and in the development of a cell-wall, whereby the oosphere is transformed into an oospore.

60.—Essentially the same kind of union takes place in the nearly related parasitic group, the *Peronosporeæ*. The only difference is that here the antheridium (Fig. 39, *n*) comes in direct contact with the oosphere (*o*) by means of a projecting tube, and through this tube the protoplasm masses of the two cells unite. The absence of motile spermatozoids in this case is probably connected with the fact that these plants live in the tissues of land plants, instead of being immersed in water.

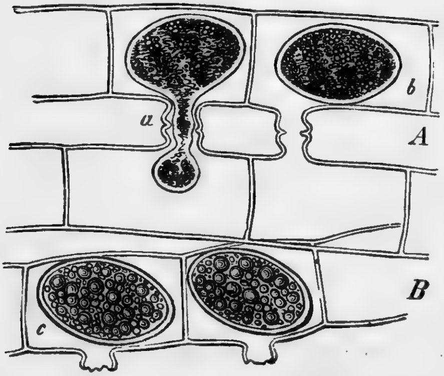


Fig. 37.—Filaments of *Spirogyra longata*; in *A*, at *a* the protoplasm is passing from the lower cell to the upper; at *b* the union of the two protoplasmic masses is completed; in *B* the protoplasmic masses have secreted thick walls, thus completing the formation of the new cells. × 550.—After Sachs.

61.—The first cell of the embryo in mosses is the result of a union of cells differing greatly in size. The larger cell lies at the bottom of a flask-shaped organ, the archegonium (Fig. 40, *B*, *b*); the smaller, the spermatozoids, are developed by the internal cell-division of another organ, the antheridium (Fig. 41, *A*). The spermatozoids, as in Vaucheria, are naked masses of protoplasm, provided with cilia, by means of which they swim freely through the water (Fig. 41, *B*). Upon coming in contact with the large cell in the archegonium they fuse with it, and thus make a new cell.

62.—In Phanerogams the first cell of the embryo is the result of the union of the protoplasm contained in the pollen-cell with that in the embryo sac. Here again the two

masses come in direct contact by means of a tube (the pollen tube) which touches with its lower extremity the embryonic vesicle.

(*a*) The foregoing classification of the modes of cell-formation differs in many respects from that given by Sachs in the fourth edition of his "Lehrbuch." His classification as there given is as follows:

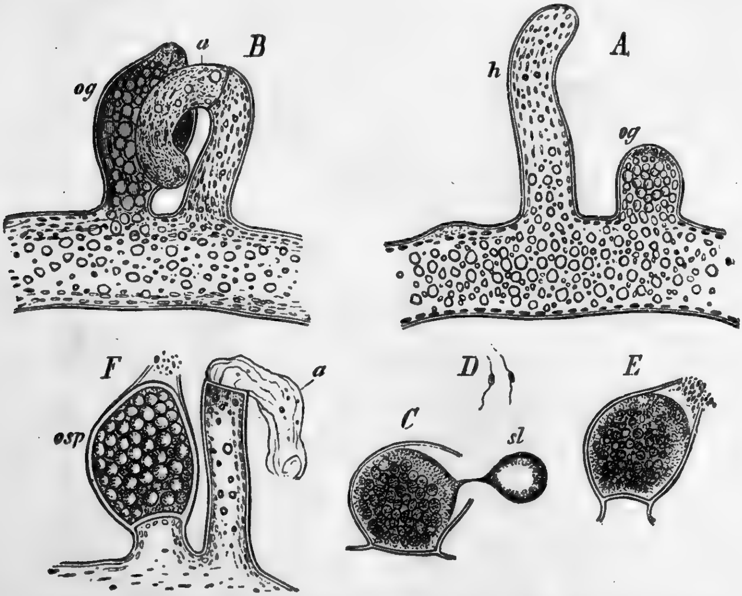


Fig. 38.—*Vaucheria sessilis.* *A*, origin of the lateral branches, *og* (*oogonium*), and *h* (*antheridium*), from the filament; *B*, the branch *a* (the same as *h* in *A*) has its terminal portion cut off by a partition; in *og* the protoplasm is becoming greatly condensed; *C*, the same as *og* of *B*, but further advanced (now called an *oosphere*) and the wall burst open, permitting the escape of a drop of mucilage *sl*; *D*, small motile cells (spermatozoids) from the terminal cell of *a* in *B*; *E*, the same as *C*, but a little later—the spermatozoids are entering through the opening; *F*, *a*, the branch *a* in *B*, with the terminal cell now empty, on account of the escape of the spermatozoids; *osp*, the same as *E*, and *og* in *B*, after union with the spermatozoids—the protoplasm is surrounded by a thick cell-wall and it is now called an oospore. × 100.—After Sachs.

A.—Formation of Reproductive Cells.

1. Rejuvenescence.
2. Conjugation.
3. Free Cell-Formation.
4. Formation of Reproductive Cells by Division, which is made to include the formation of pollen, the spores of mosses and ferns, and the conidia, stylospores, and basidiospores of many fungi.

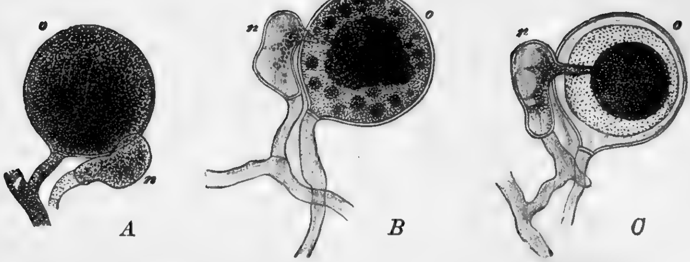


Fig. 39.—*Peronospora alsinearum.* *A*, young oogonium *o*, and young antheridium *n*, in contact with it; *B*, the antheridium *n* beginning to pierce the oogonium *o*, whose protoplasm is becoming condensed; *C*, the fine tube of the antheridium *n* has penetrated the oogonium *o*, and come in contact with its condensed and rounded protoplasm, the oosphere. × 350.—After De Bary.

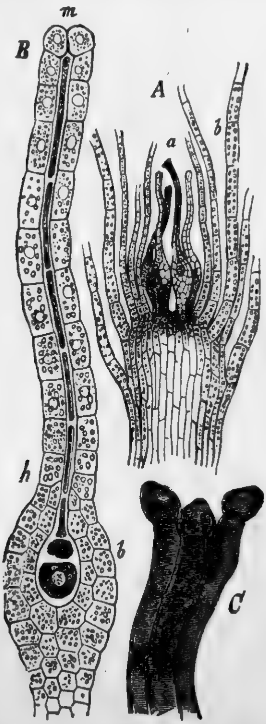


Fig. 40.

Fig. 41.

Fig. 40.—Female reproductive organs of a moss, *Funaria hygrometrica.* *A*, apex of the stem; *a*, archegonia; *b*, leaves: *B*, archegonium; *b*, base; *h*, neck; *m*, mouth; *C*, mouth of fertilized archegonium. *A* × 100, *B* × 550.—After Sachs.

Fig. 41.—Male reproductive organs of the same moss. *A*, antheridium open and permitting the spermatozoids *a* to escape; *B*, *b*, sperm-cell of another moss (*Polytrichum*), with contained spermatozoid; *c*, spermatozoid free, with two cilia at the pointed extremity. *A* × 350, *B* × 800.—After Sachs.

B.—Formation of Vegetative Cells.

1. By the progressive formation of a division wall.
2. By the simultaneous formation of a division wall.

The main objection to this classification is that its principal divisions are based upon physiological distinctions alone.

(*b*) Duchartre, in his "Éléments de Botanique," makes a very simple classification, as follows:

A.—Free Cell-Formation.

1. Intracellular.
2. Extracellular [Rejuvenescence].

B.—Formation of Cells by Division.

1. Progressive division.
2. Simultaneous division.

Note on Paragraph 56. "From the researches of Schmitz on the Myxomycetes (Sitzber. d. nieder-rhein. Ges. in Bonn, 1879), it appears that the nuclei of the cells which coalesce to form the plasmodium do not fuse, but remain distinct: this case of coalescence of cells cannot, therefore, be any longer regarded as an instance of cell-formation by conjugation." (*S. H. Vines in App. to Sachs' Text-Book of Botany. Second English Edition, p.* 945.)

CHAPTER V.

PRODUCTS OF THE CELL.

§ I. Chlorophyll.

63.—In many plant-cells definite portions of the protoplasm have a green color, on account of the presence of a peculiar chemical compound known as Chlorophyll.* The protoplasmic bodies thus colored are called chlorophyll-bodies, or chlorophyll granules, while to the coloring-matter alone, distributed in small quantity through their substance, the name chlorophyll is properly applied.

64.—The chlorophyll-bodies are of various shapes and sizes. In some of the lower plants nearly the whole of the protoplasm is colored, giving the whole cell a uniform green color. In others there are stellate or band-like chlorophyll-bodies distinct from the mass of the protoplasm of the cell; the band-like bodies are straight, or more commonly spiral (Fig. 42). In the great majority of cases, however, the chlorophyll-bodies are simple rounded granules of such minute size that many are contained in a single cell (Fig. 43). The chlorophyll may be dissolved out of its protoplasmic vehicles, leaving the latter with the appearance and chemical properties of ordinary protoplasm.

65.—The exact *chemical composition* of chlorophyll is not known. As obtained by the evaporation of its alcoholic solution it is a green resin-like powder, insoluble in water. From the partial analyses of Kromayer it is probable that it contains carbon, hydrogen, nitrogen, and oxygen, and there are good reasons for believing that iron is also one of its constituents.

---

* Chlorophyll is also found to a limited extent in the animal kingdom.

66.—With few exceptions chlorophyll is not found in cells which are not exposed to the action of light.* When ordinary green plants are removed for some time from the light, the chlorophyll disappears from the chlorophyll-bodies, and leaves them colorless. The same decoloration also takes place when a plant is deprived of iron as one of the constituents of its food. The disappearance of chlorophyll takes place normally in higher plants when the cells lose their activity. In the case of leaf-cells, upon the approach of autumn the chlorophyll appears to be removed to other portions of the plant.

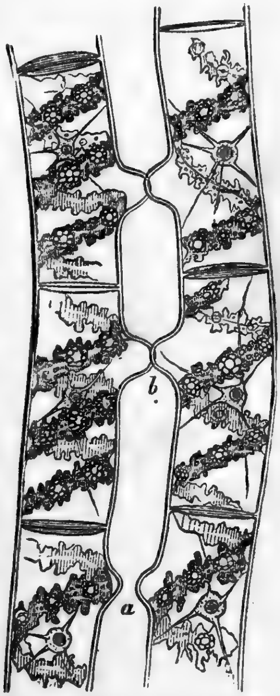


Fig. 42.—Two filaments of *Spirogyra longata*; the chlorophyll is in spiral bands; in the centre of each cell is a nucleus, with radiating strings of protoplasm. × 550.—After Sachs.

(*a*) The cells of many *Palmellaceæ*, and many zoospores—*e.g.*, of *Œdogonium* and *Vaucheria*—furnish good examples of the coloration of nearly the whole body of protoplasm.

In *Zygnema* the chlorophyll-bodies are stellate, and in *Spirogyra*, spiral.

In *Vaucheria* there are multitudes of roundish or slightly angular chlorophyll-bodies, which line the interior of the large cells. The chlorophyll in the leaves of many mosses may be easily studied, even without making sections; in them the chlorophyll-bodies are roundish in outline. In the higher plants thin cross-sections of the leaves afford the best means for the examination of their chlorophyll-bodies, which are uniformly of a simple rounded outline.

(*b*) Chlorophyll is soluble in alcohol, ether, chloroform, benzine, essential and fatty oils, hydrochloric and sulphuric acids, and these may be used

* The cotyledons of many Coniferæ acquire a green color even in total darkness. The embryo of *Phoradendron* is green in the unopened seed, and in certain seeds with thick coats, which are impervious to light (*e. g.*, in some *Cucurbitaceæ*), a chlorophyll-bearing layer of cells surrounds the embryo.

for obtaining solutions. In transmitted light the alcoholic solution is green, but when viewed by reflected light it appears to be red.

When an alcoholic solution of chlorophyll is boiled for a few minutes with an alcoholic solution of potash, and then neutralized with hydrochloric acid two substances are obtained: the one as a yellow precipitate, named *Phylloxanthine*, and the other a blue substance dissolved in the supernatant liquid; by evaporation the latter may be obtained as a blue powder, named *Phyllocyanine*.

Fig. 43.—Chlorophyll granules in cells of the leaf of a moss, *Funaria hygrometrica*. *A*, granules of chlorophyll with contained starch grains, embedded in the protoplasm of the cells. *B*, separated chlorophyll granules containing starch; *a* and *b*, young granules; *b′ b″*, granules dividing; *c*, *d*, and *e*, old granules; *f*, granule swollen up by the action of water; *g*, starch grains left after destruction of chlorophyll granule by the action of water. × 550.—After Sachs.

(*c*) The importance of iron in giving a green color to plants is easily demonstrated by growing young plants of Indian corn in solutions containing no iron. The first-formed leaves are green, but subsequently only colorless ones are produced; after the addition of iron in the form of ferric sulphate or ferric chloride, the colorless leaves become green in the course of a few days.

The importance of light in the production of chlorophyll is shown in the etiolated shoots of the potato when grown in a dark cellar; the same thing may be shown by germinating the seeds of many common plants in dark boxes.

(*d*) The disappearance of chlorophyll is seen in the common operation of blanching celery for table use, and in the blanching of grass-blades under boards. Upon gradually exposing such colorless plants to the light chlorophyll is produced.

(*e*) Many plants which contain chlorophyll have their green color hidden by the presence of some other coloring-matter. Sometimes this is dissolved in the water contained in the vacuoles; this is the case in *Coleus*, in which the dissolved pigment is red. In young plants of *Atriplex* the epidermal cells are filled with such a red solution, hiding the green chlorophyll-bearing cells underneath. In cer-

tain algæ the chlorophyll-body itself contains other coloring-matters—soluble in water, however—in addition to the chlorophyll. In *Florideæ* (red sea-weeds) this extra coloring-matter is red; in *Fucaceæ*, brown; in *Diatomaceæ*, yellowish; and in *Oscillatoriæ*, blue.

In the degradation of chlorophyll, which takes place in the walls of the antheridia of mosses, and in the ripening of some fruits of Phanerogams, other colors than green are produced.

(*f*) Plants which live parasitically upon others, as the Dodder, and those which are saprophytic in habit, as some fungi, are usually destitute of chlorophyll; where the parasitism is only partial, as in *Castilleia* and *Gerardia*, or where the food used (stolen) by the parasite is unassimilated, as in the Mistletoe, chlorophyll is present. In the true *parasites* (found mainly among the fungi) chlorophyll is never present.

(*g*) The colors of flowers are produced in various ways. In some cases rounded masses, apparently protoplasmic in their nature, contain a red (*e.g.*, *Adonis*), orange (*e.g.*, *Zinnia*), or yellow (*e.g.*, *Cucurbita*) coloring-matter. In other cases the pigment is dissolved in the watery fluid of the cells; blue and violet colors are mostly produced in this way. White petals are so because their external layers of cells are filled with air. An important difference beween chlorophyll and the pigments of flowers, is that the latter appear not to be dependent upon light for their production; this may be shown by enclosing branches of morning-glory (*Ipomœa*) bearing young flower-buds in a dark chamber; when the flowers expand they will be seen to have their natural colors.

§ II. Starch.

67.—Next to chlorophyll, one of the most important products of the plant-cell is *starch*, an organic compound closely related to sugar and cellulose, and represented by the empirical formula $C_{12}\ H_{20}\ O_{10}$. It occurs in the form of whitish or semi-transparent, rounded or slightly angular stratified grains, and is generally found closely packed in the interior of certain cells.

68.—The *form* of starch grains varies greatly in different plants, and considerably even in the same plants; nevertheless, the general appearance of the grains in each plant is so characteristic that the different kinds of starch may be quite easily distinguished. In every case the grains have more or less clearly defined lines, which are concentrically arranged about a nucleus * (Figs. 44 and 45). In some cases (excep-

* The nucleus is called the *hilum* by some authors, a term which

tionally in some plants and uniformly in others) two or more nuclei occur in each grain; by growth such grains become compound and may finally separate into as many parts as there are nuclei.

69.—The *molecular structure* of the starch grain has been determined to be similar to that of plant-cellulose. It is regarded as composed of molecules, each of which is surrounded by a watery layer of greater or less thickness. Growth takes place by the intercalation of new molecules between the previously formed ones—in other words, by intussusception, exactly as in the case of the cell-wall. During the formation of the grain, in certain portions of it the watery layers surrounding the molecules become thicker. When seen by transmitted light such more watery parts appear darker than those which are less watery, and an examination shows that they surround the nucleus on all sides in a concentric manner. In this way the starch grain comes to be made up of alternating layers of more and less watery substance. Every watery layer is thus between two layers which contain less water, and so every less watery one lies between two more watery ones. As an increase in the amount of water in any portion of the starch grain decreases the density of that portion, the layers just described may be distinguished as of greater density when having less water and of less density when having more water.

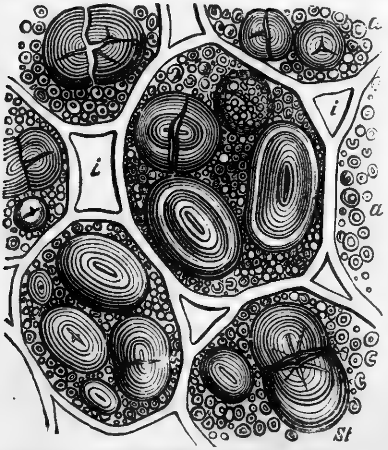


Fig. 44.—Cells from the cotyledon of the pea, (*Pisum sativum*). *St*, starch grains with nucleus and concentric striæ; *a*, granules of aleurone; *i*, *i*, intercellular spaces. × 800.—After Sachs.

---

should be abandoned, as it was originally given under the mistaken notion that it was the point of attachment of the starch grain while growing.

70.—There are two kinds of starch in every starch grain. The great mass is made up of a more readily soluble form, the *granulose*, while the remainder, amounting to not more than from two to six per cent of the whole grain, is less soluble, and bears some resemblance to cellulose; it is distinguished as *starch-cellulose*. These two forms are intimately combined throughout the whole starch grain, so that upon the removal of the granulose by solution a perfect skeleton of the grain still remains.

71.—The first formation of starch appears to take place in the chlorophyll-bodies when they are exposed to the light (Fig. 43, *B*, p. 52, and Fig. 36, p. 45). The grains thus formed are extremely minute, and of different shapes and sizes in each chlorophyll-body; they do not remain and grow into larger grains, but are dissolved upon the withdrawal of light. Thus the starch formed during the day disappears during the night and is doubtless carried to other portions of the plant.

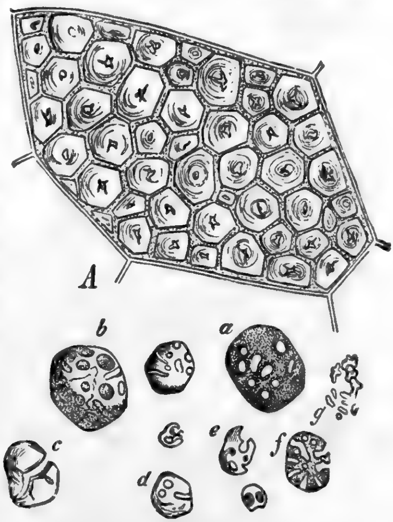


Fig. 45.—Cell of endosperm of Indian corn, containing polygonal starch grains, separated by thin plates of protoplasm. In the figures *a* to *g*, the starch grains, taken from a germinating Indian corn grain, are becoming dissolved and disintegrated. × 800.—After Sachs.

72.—The formation of ordinary starch grains always takes place in protoplasm; in fact, they may be said to be secretions from the protoplasm, just as cellulose is said to be a secretion. In a cell whose cavity is filled with full-grown starch grains the protoplasm has almost entirely disappeared, only small portions of it remaining as thin plates or scales between the grains (Fig. 45).

(*a*) Starch occurs in nearly all chlorophyll-bearing plants; it is absent only in *Nostocaceæ*, *Oscillatoriæ*, and other algæ whose chlorophyll-

bodies contain an additional blue pigment. It is present in many plants which are destitute of chlorophyll; this is the case with the parasitic Phanerogams; it occurs, for example, in the stem of *Cuscuta*, and in the underground portions of *Orobanche* and *Lathræa*. From chlorophyll-less Thallophytes (fungi), with rare exceptions, it appears to be absent.*

(*b*) The best common examples for the study of fully formed starch grains are the following, viz., tubers of the potato, seeds of the bean and pea, grains of wheat, Indian corn, rice, etc. Oat-starch and that of the crocus corm exist in the form of compound grains. Of those named, the starch grains of the potato and the bean are the largest, being about .07 mm. (.003 inches) in diameter, while those of rice are the smallest, being about .007 mm. (.0003 inches) in diameter.

(*c*) The test which is characteristic of starch is its blue coloration when treated with a weak solution of iodine. When the solution is strong the color is so intense as to appear black. A careful examination shows that it is only the granulose which is thus colored blue by iodine, but on account of its much greater quantity and its intimate mixture with the starch-cellulose, the blue granulose gives its color to the whole grain.

(*d*) An indication of the correctness of the present view as to the structure of the starch grain and the cause of stratification may be obtained in two ways, as follows: 1st, by thoroughly drying the grain by evaporation of its water or by placing it in absolute alcohol; all parts having now equal amounts of water, the striæ disappear; 2d, by rendering all parts of the grain capable of absorbing large quantities of water, as may be done by means of a weak solution of potash, as in this way the *difference* in the amount of water in different layers being destroyed, the striæ disappear as before.

The drying process just referred to reveals another structural peculiarity, viz., that the interior portions of the starch grain contain the greatest amount of water. On drying, internal fissures appear, radiating from a central cavity and having a narrower diameter as they pass outward, showing that the loss of water is greatest in the interior.

(*e*) The separation of the granulose from the starch-cellulose may be accomplished in the following ways: (1) by allowing the starch grains to remain for a long time in a weak solution of hydrochloric or sulphuric acid; the acid solution must not be strong enough to cause the grains to swell; (2) by the action of saliva at a temperature of 40° to 47° C. (105° to 117° Fahr.). In either case the granulose is removed and the starch cellulose remains as a skeleton. Upon treatment with a solution of iodine the skeleton is colored brown instead of blue. Other

---

* Hofmeister, in "Lehre von der Pflanzenzelle," from which the preceding statements have been mainly taken, states that starch granules occur in the oospores of *Saprolegniæ*.

agents, as organic acids, diastase, and pepsin, also are solvents of granulose.

(*f*) The natural solution of starch grains takes place in the cells of living plants in a way somewhat similar to the artificial removal of granulose. The process is not, however, so regular and uniform; holes and irregular excavations are formed in the grains, sometimes with the removal of the granulose only, and in other cases with the solution of the whole substance; sooner or later the grains break up into pieces, and by a continuation of the process of solution they soon disappear (Fig. 45, *a*, *g*). Sachs maintains that starch may thus be dissolved in the cotyledons of the bean and transferred to other parts of the plantlet, reappearing in the form of grains without undergoing chemical change or conversion into sugar.

(*g*) Observations upon the formation and disappearance of starch grains in the chlorophyll-bodies are best made with *Spirogyra*. By keeping healthy filaments of this plant in darkness for some time the starch disappears; upon exposure to direct sunlight the formation of starch begins again in about two hours; in diffused daylight it begins several hours later. Other plants with thin tissues may also be used, as, for example, the thin leaves of mosses, etc.

(*h*) The development and growth of starch grains may be studied in the ripening grains of Indian corn, by making extremely thin sections at different stages of the ripening process. They always appear at first as minute solid globular masses in the protoplasm.

§ III. Aleurone and Crystalloids.

73.—In the ripening of seeds and the maturation of tubers the loss of water by the protoplasm gives rise to a number of poorly understood forms of albuminous matter. Two of the most noteworthy of these are *Aleurone*, and the crystal-like bodies known as *Crystalloids.*

74.—Aleurone occurs in the form of small rounded grains, sometimes occupying a great portion of the cavity of the cell (Fig. 44, *a*, p. 54). They are soluble in water,* or in water containing a little potash; but are insoluble in alcohol, ether, benzole, or chloroform. They frequently contain other bodies enclosed in their substance, as crystalloids (described below), globoids (composed of a double calcium and magnesium phosphate), and crystals of calcium oxalate.

* The aleurone grains of *Cynoglossum officinale* are stated by Sachs not to be soluble in water.

75.—Aleurone grains appear in seeds during the last stages of ripening. In the turbid cell-contents, as the loss of water proceeds small globular masses of albuminous matter appear, and afterward increase their size; by the continued loss of water they become harder and of a more definite outline. In the germination of the seed the aleurone grains dissolve, and the protoplasmic contents of the cells assume very nearly the condition they held before the final changes in the seed which produced the aleurone.

Aleurone may be studied in the seeds of the bean, pea, vetch, and lupine, and in acorns, chestnuts, horsechestnuts, and the bran-cells of the oat-grain.

The development of aleurone grains may be best studied in the ripening seeds of the peony.

76.—As with the grains of aleurone, the nature of *crystalloids* is not fully understood. They are quite certainly modifications of protoplasm, and not true crystals, although they are bounded by plane surfaces, have sharp edges and angles, and when viewed by polarized light bear a resemblance to crystals. Their deportment with reagents, however, is similar to that of protoplasm; thus, under treatment with iodine, or nitric acid and potash, and in their coagulability, they show a protoplasmic nature. They possess the power of imbibing water, but are not dissolved in it, and in a dilute solution of potash they swell greatly, at the same time altering their angles. They are insoluble in alcohol. In dilute acids or glycerine one portion of their substance is removed, leaving a skeleton.

77.—In form they are cubical, tetrahedral, octahedral, rhombohedral, and of other shapes, and there is generally such irregularity in their forms that it is difficult to determine to which crystal system they belong. In most cases they are colorless, but in some plants they contain a coloring-matter which may be removed by alcohol and acids.

(*a*) Common examples for study may be obtained from the parenchyma-cells beneath the skin of the potato tuber, in which they are cubical or tetrahedral, and imbedded in the protoplasm.

They may be obtained from the Brazil-nut (*Bertholletia excelsa*) by placing portions of the crushed seed in a test-tube and agitating it with ether; the crystalloids, which settle to the bottom, are tabular.

Thin sections of the seeds of the Castor Bean (*Ricinus communis*), after the removal of other substances by soaking in water for some time, show tetrahedral or octohedral crystalloids.

(*b*) Aleurone and the crystalloids furnish the greater part of the albuminoid portions of edible grains. The amount of albuminoids is presumably an indication of the amount of aleurone and crystalloids. The percentage of albuminoids in some air-dry grains and seeds is given below:*

Rice	7.5
Barley	9.5
Indian Corn	10.
Oats	12.
Wheat	13.
Pea	22.4
Bean	25.5
Vetch	27.5
Lupine	34.5

Aleurone and the crystalloids appear to be resting states of protoplasm analogous to the resting states (sclerotia) of the plasmodia of Myxomycetes.

§ IV. Crystals.

78.—In many plants *crystals* of various forms occur either in the cavities of cells, or in the substance of the cell-walls, or even in intercellular spaces. They are, in the greater number of cases, composed of calcium oxalate, and are widely distributed throughout the vegetable kingdom, but appear to be most numerous in the higher groups, and least so in Bryophytes and Pteridophytes.

79.—It is common to distinguish the acicular (needle-shaped) crystals from the other forms under the name of *Raphides;* these have but two equivalents of water of crystallization in their composition ($[Ca\ O]_2\ C_4\ O_6 + 2\ H_2\ O$). They are found in the cavities of parenchyma-cells, and lie parallel together in bundles of ten to fifty or more. Upon slight pressure the crystals separate and escape (Fig. 46).

The other crystals of calcium oxalate assume various forms, such as prisms, octahedra, etc. They have six equiv-

* These percentages are from Wolff and Knop's tables, as given by Professor S. W. Johnson in his valuable "How Crops Grow."

alents of water of crystallization ($[Ca\,O]_2\,C_4\,O_6 + 6\,H_2\,O$). They may be simple (Fig. 47) or combined into compound crystals (Fig. 46); many of the former are sometimes found imbedded in the substance of the cell-wall of the fibre-cells of certain Gymnosperms (Fig. 47). Simple crystals occur also within the cell-cavities of many plants. The compound forms are very various; they almost always occur in cell-cavities, as in the beet (Fig. 46); and it not infrequently happens that both simple and compound crystals are found in the same plant, even in contiguous cells, as is the case in the onion bulb.

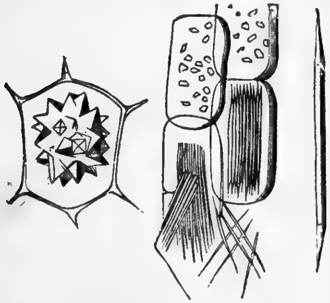


Fig. 46.—Crystals of calcium oxalate. The right-hand portion of the figure shows two raphis-cells of the Rhubarb, with their contained raphides, and one crystal enlarged. On the left is a crystal from the beet. Much magnified.

80.—Crystals of calcium carbonate ($Ca\,CO_3$) occur less frequently than those just described. Their most striking form is that seen in the structures named cystoliths (Fig. 48). These possess a curious structure; a club-shaped or stalked outgrowth of cellulose projects into the interior of a cell, and upon and in this multitudes of small crystals are grouped. Other forms of calcium carbonate crystals are to be found in plants—*e.g.*, in the Myxomycetes.

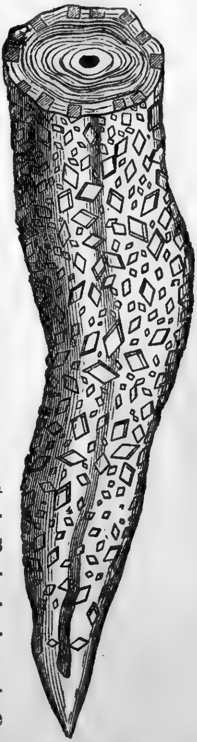


Fig. 47.—Crystals of calcium oxalate in the cell-wall of *Welwitschia mirabilis*.—After Sachs.

According to some observers, crystals of calcium phosphate, calcium sulphate, and silica are occasionally to be met with in plants.*

* See an article on plant-crystals by Dr. Lancaster in the *Qr. Jr. of Mic. Science*, 1863, p. 243; also articles by Professor Gulliver in the same journal for 1864, 1866, and 1869.

(*a*) In studying plant-crystals it is only necessary in most cases to make thin longitudinal sections, and to mount in the usual way in water.

(*b*) The calcium carbonate crystals may be distinguished from those of calcium oxalate by treatment with hydrochloric acid, which dissolves both, the former with effervescence, the latter with none. Under treatment with acetic acid the calcium carbonate crystals dissolve (with effervescence, of course), while those of calcium oxalate do not dissolve.

(*c*) Acicular crystals, or raphides, may be best obtained from the Evening Primrose, *Epilobium*, Fuchsia, and other Onagraceæ, also from the Balsam (*Impatiens Balsamina*), Garden Rhubarb, and the new growths of the Virginia Creeper, and the grape-vine.

Raphides may also be obtained from some of the Monocotyledons with equal ease, *e.g.*, *Tradescantia*, Indian turnip (*Arisæma*), *Calla*, *Narcissus*, Lily-of-the-Valley, etc.

(*d*) The other crystal forms are obtainable from the bark of the locust (*Robinia*), elm, *Hoya*, leaves of *Begonia*, bulb-scales of onion, garlic, and leek, the root-stock of *Iris*, etc.

(*e*) Cystoliths may be readily studied by making cross-sections of the leaves of *Urtica*, mulberry, hop, hemp, fig, *Celtis*, and other *Urticaceæ*. They are said by Sachs to occur only in this order and the *Acanthaceæ*.*

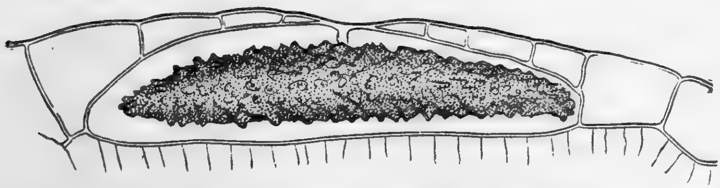


Fig. 48.—Cystolith from the epidermis of the upper surface of the leaf of *Urtica macrophylla*, from a cross section of the leaf. × 225.—After De Bary.

(*f*) Plant-crystals appear to be surrounded by a thin layer of protoplasm; probably they are separated out from the cell sap only through the influence of protoplasm. It is further probable that they are residual products of chemical actions in the plant, and, as they appear never to be made use of by the plant, we must regard them as to a certain extent of the nature of excretions.

* "Lehrbuch," 4te auf., p. 69. However, cystoliths, or structures very much like them, may be found in the leaves of *Ceanothus prostratus* of Nevada and California. The student is referred to De Bary's "Vergleichende Anatomie der Vegetationsorgane der Phanerogamen und Farne," Chapters I. and III., for a full discussion of the subject of plant-crystals, and for a list of plants containing them. The articles referred to in *Qr. Jour. Mic. Science* will also prove helpful.

§ V. The Cell Sap.

81.—All parts of a living cell are saturated with water. It enters into the structure of the cell-wall; it makes up the greater part of the bulk of the protoplasm, and it fills the vacuoles. It holds in solution (not necessarily, however, in equal proportions in all its parts) the food-materials absorbed by the plant, and the surplus soluble products of assimilation and metastasis.

82.—Among the more important substances dissolved in the cell sap are Sugar and Inulin. Of the former there are two varieties, viz., sucrose, or cane sugar ($C_{12} H_{22} O_{11}$), and glucose (or lævulose), or fruit sugar ($C_{12} H_{24} O_{12}$), which differ in their sweetness, as well as in other properties.

83.—Cane sugar exists in great abundance in the cell sap of sugar cane, sugar maple, sugar beet, Indian corn, and in greater or less quantity in nearly all higher plants. Fruit sugar, as its name indicates, is found in many fruits, sometimes mixed with cane sugar; thus in grapes, cherries, gooseberries, and figs it is the only sugar present, while in apricots, peaches, pine-apples, plums, and strawberries it is mixed with cane sugar.

84.—Inulin ($C_{12} H_{20} O_{10}$) is a substance related to starch and sugar, and found mainly in certain Compositæ, *e.g.*, *Dahlia, Helianthus, Inula, Taraxacum*, etc. It may be separated from the cell sap by alcohol, glycerine, and other agents, and it then assumes the form of sphere-crystals. By boiling in dilute hydrochloric or sulphuric acid inuline is transformed into glucose.

§ VI. Oils, Resins, Gums, Acids, and Alkaloids.

85.—The fixed oils, as olive, castor, linseed, and palm oil, are secreted in many plant-cells, particularly in the seeds. They occur as separated drops among the other contents of the cells. In some instances the tissues contain from thirty-five to forty per cent of oil.

86.—The essential oils, the resins, and gums are mainly the products of special cells in the plant. These secreting cells

are usually thin-walled and filled with granular protoplasm. The secretions are in some cases collected in drops in the cell-cavity, in others they are caused to pass through the cell-wall, while in still other instances the cell-wall ruptures, and permits the escape of the secreted matter.

87.—There are three classes of essential oils, distinguished by their chemical composition, as follows:

(*a*) The *pure hydrocarbons;* these are represented by the formula $C_{10}H_{16}$. Oil of turpentine, obtained from the crude turpentine of various Conifers, is the type. Oil of lemons, oil of caraway, and oil of thyme are also of this class.

(*b*) The *oxidized essences,* in addition to carbon and hydrogen, have oxygen in their composition. Of this nature are camphor ($C_{10}H_{16}O$), essence of cinnamon, essence of wintergreen, etc.

(*c*) The *sulphuretted essences* contain sulphur. To this class belong the essential oils in mustard, horseradish, and other Cruciferæ, in onions, garlic, asafœtida, etc. That in garlic, which may be taken as the type, is a sulphide, ($[C_3H_5]_2, S$), while that of the mustard is a sulpho-cyanide (C_3H_5, CNS).

88.—Resins are much like the essential oils in composition, and are generally associated with and dissolved in them. When separated from the essential oils by heat, the resins are transparent or translucent brittle solids, insoluble in water, but soluble in alcohol. Common rosin, which is the residue left when the crude turpentine derived from several species of pines is distilled with water, may be taken as the type. It is an oxidized hydro-carbon, *i.e.*, it contains carbon, hydrogen, and oxygen.

89.—Gums. Under this name many different kinds of products are commonly included. Some of them are without doubt related to the resins, while others are allied to starch and sugar. Of the latter kind gum-arabic ($C_{12}H_{22}O_{11}$) is the type, and allied to it are cerasin (from the cherry), bassorin (gum tragacanth), and vegetable mucilage, which is abundant in mallow roots.

90.—Pectin, or vegetable jelly ($C_{32}H_{48}O_{32}$), is related to the foregoing; it forms, when moist, a transparent jelly, and

dries into a translucent mass. It gives the firmness and consistence to apple, currant, and other fruit jellies. Unripe fruits contain a substance insoluble in water, alcohol, and ether, which, during the process of ripening, or under the action of heat, acids, and ferments, is converted into pectin.

91.—In addition to oxalic acid ($C_2 H_2 O_4$), which is found generally combined with calcium, there are other vegetable acids, some of which are even more common; they occur either free, or united with organic or inorganic bases.

(*a*) *Malic Acid* ($C_4 H_6 O_5$) is abundant in many sour fruits —*e.g.*, apples, cherries, strawberries, currants, etc.; it is likewise abundant in rhubarb, where it accompanies oxalic and phosphoric acids.

(*b*) *Tartaric Acid* ($C_4 H_6 O_6$) occurs in the grape, tamarind, berries of the mountain ash (unripe), and other plants.

(*c*) *Citric Acid* ($C_6 H_8 O_7$) is found in abundance in the lime, lemon, and other fruits of the Aurantiaceæ. It also occurs in other sour fruits associated with malic acid, as in gooseberries, raspberries, strawberries, cherries, etc.

(*d*) *Tannic Acid* ($C_{27} H_{22} O_{17}$) occurs in the bark and leaves of oak, elm, willow, and many other trees, in the wood and bark of sumach and whortleberry, and the roots of some Rosaceæ and Polygonaceæ, and gives to them their astringency.

Nearly related to tannic acid is quinic acid, which occurs in the bark of *Cinchona* (Peruvian Bark) in combination with organic bases, of which quinia is the most important.

There are many other substances which occur in plants as the products of cells—*e.g.*, the vegetable alkaloids, many coloring-matters, etc. As, however, this whole matter belongs rather to Organic Chemistry, it will not be carried further in this place.

CHAPTER VI.

TISSUES.

§ I. The Various Aggregations of Cells.

In the organisms which compose the vegetable kingdom cells are found principally under the following conditions of aggregation :

92.—(1.) **Single Cells.** A large number of the lower plants, during all or a considerable part of their existence, are composed of single cells. They may be round, as in *Saccharomyces* and *Protococcus*, or elongated or even filiform, as in certain Bacteria. It is only in the lowest groups that

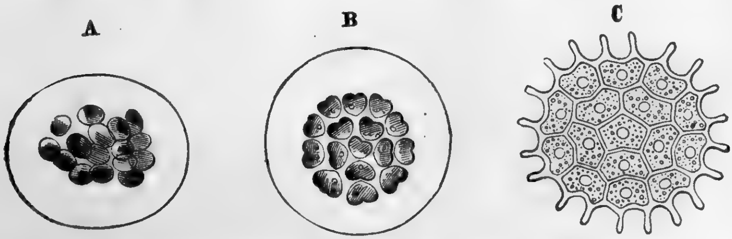


Fig. 49.—*Pediastrum granulatum.* *A*, the young cells in their motile state, enclosed in the membrane of the mother-cell. *B*, the young cells beginning to arrange themselves in a cell-family. *C*, the cell-family fully developed.—After Braun.

adult plants are composed of single cells, but it is an embryonic condition of all others.

93.—(2.) **Families,** or **Spurious Tissues.** There are some cases in which cells which are at first distinct afterwards become united more or less closely into a common mass, which may be denominated a Cell-Family, or Spurious Tissue.

(*a*) *Pediastrum* and *Hydrodictyon* furnish the best examples of true

cell-families; in both cases separate motile cells (zoospores) in a mother-cell arrange themselves in a definite manner, and gradually unite into a family resembling the parent plant (Fig. 49). By the breaking up of the wall of the mother-cell the new family is set free.

(*b*) In some fungi the cells composing the vegetative threads (hyphæ) unite loosely with one another into a mass. In some cases the union is so slight that the hyphæ may be separated with the greatest ease, while in others it approaches the density and firmness of true tissues (Fig. 50). While the term Cell-Family may be applied to such aggregations of cells, the common one of Spurious Tissue is to be preferred.*

(*c*) In the embryo sac of Phanerogams the cells are at first separate;

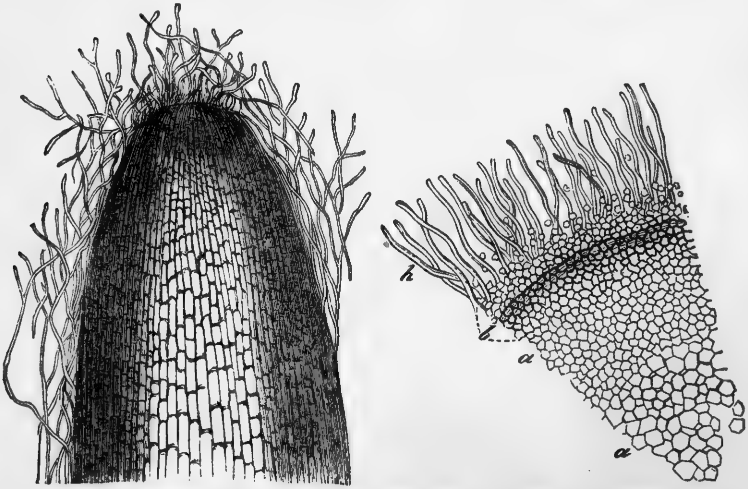


Fig. 50. — *Rhizomorpha subcorticalis* (the compact mycelium of a fungus). The left hand figure shows a longitudinal section of the growing end of a young shoot. The right hand figure shows a cross-section of the same; *a*, the central pith-like portion; *b*, the cortical portion of smaller cells; *h*, the hairy coat, which is often wanting. × 100.—After De Bary.

these afterward unite into a mass which cannot be distinguished by any structural character from a true tissue. (See Fig. 33, p. 43.) As, however, the component cells were originally separate, the resulting mass must be classed with the spurious tissues.

94.—(3.) **Fusions.** It frequently happens that the separating walls of contiguous cells are absorbed and their cell-cavities merged into one. In this way long tubes (vessels)

* This is the "Tela contexta" of some authors.

are formed. These may extend in any direction, but they generally run parallel to the axis of that part of the plant in which they are found. Other cell-fusions give rise to irregular branching tubes, or they may even form an extended network (*e.g.*, in the laticiferous tissue of Cichoriaceæ, Fig. 65, p. 75).

95.—(4.) **Tissues.** A tissue may be defined as an aggregation of similar cells (or cell-derivatives) connately united. There are three conditions of aggregation :

(*a*) *Cell-rows.* In these the cells are united by their ends into a row or filament. Such simple tissues result from cell-fission in one direction only. In some cases, as in *Oscilla-*

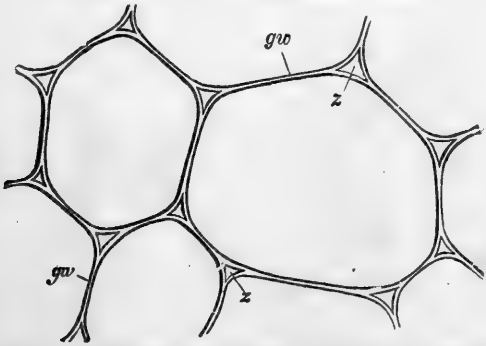


Fig. 51.—Succulent parenchyma from the stem of Indian corn ; transverse section. *gw*, simple plate of cellulose, forming the partition-wall between two cells ; *z*, *z*, intercellular spaces caused by splitting of the walls during rapid growth. × 550. —After Sachs.

toria, the cells are short and broad, while in others—*e.g.*, *Spirogyra*, *Zygnema*, and the hyphæ of many fungi—they are cylindrical or greatly elongated. Numerous cases occur in the higher plants, the most familiar being jointed hairs.

(*b*) *Cell-surfaces* are composed of a single layer of cells. They result from cell-fission in two directions. Examples may be found in many Ulvaceæ, and in the leaves of some Bryophytes.

(*c*) *Masses.* Where the cell-fission has been in three directions the result is a mass of greater or less solidity. Frequently, through cell-fusions, the elements which compose such masses are cell-derivatives, instead of cells ; these may be regarded as tissues of a higher order.

96.—The Cell-wall in Tissues. In tissues the walls which separate contiguous cells are at first simple and homogeneous. The plate of cellulose which first forms between two sister masses of protoplasm in cell-fission is a single one, the common property, as it is the common secretion, of the protoplasm masses. As the wall becomes older and thicker, and stratification takes place, it shows a line of separation into two halves; this may become so well marked as actually to result in the splitting of the wall, as is the case in succulent tissues when, on account of a particular kind of tension, intercellular spaces are formed in the angles between the cells (Fig. 51).

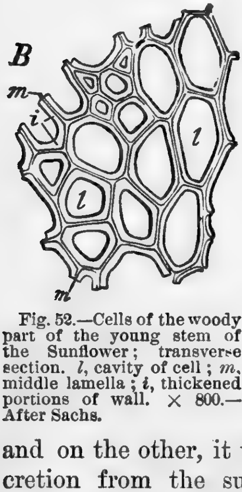


Fig. 52.—Cells of the woody part of the young stem of the Sunflower; transverse section. *l*, cavity of cell; *m*, middle lamella; *i*, thickened portions of wall. × 800.—After Sachs.

97.—By a still further differentiation, after a considerable thickness of the wall has been attained, there may arise a common middle lamella, which appears at first sight to lie between the original cell-walls (Fig. 52). This middle lamella, which is simply the result of a particular stratification, was long mistaken for an intercellular substance, and two theories were held as to its nature. On the one hand, it was supposed to be an original common matrix, in which the cells themselves were imbedded; and on the other, it was held to be of the nature of an excretion from the surrounding cells into the intercellular spaces. The first of these theories was possible only so long as the knowledge of the origin and development of cells was exceedingly defective. The second theory is rendered extremely improbable by our present knowledge of the mode of growth of the cell-wall by intussusception.

Until recently another view has been largely held, namely, that the middle lamella was to be regarded as the original common wall of the cells, and that the remaining portions were after-deposits upon it. This view gave rise to the terms Primary Cell-wall and Secondary Cell-wall, which are still used to some extent. As this explanation of the structure rests upon the all-but-abandoned theory of the thickening

of the cell-wall by the addition of successive internal layers, and is directly contradicted by the well-established doctrine of growth by intussusception, it must be regarded as erroneous.

In some cases, as in the wood of *Pinus sylvestris,* the differentiation is so great that three lamellæ are formed : (1) the common middle one, (2) an inner, and (3) an intermediate one. (Fig. 16, p. 26.)

§ II. The Principal Tissues.

98.—There are very many kinds of tissues, distinguished from each other by characters of greater or less importance. They all, however, pass into one another by almost insensible gradations ; hence by noting all the slight differences we may make a long list of tissues ; while by noting the similarities and gradations, all, or nearly all, the forms may be reduced to one. The principal varieties only will be noticed in this place ; each one, as here described, includes many varieties.

Fig. 53.—Meristem-cells of stem of *Vicia faba* in process of division. × 300.—After Prantl.

99.—Parenchyma. This is the most abundant tissue in the vegetable kingdom ; it is at once the most important and the most variable. As here restricted it is composed of cells whose walls are thin, colorless, or nearly so, and transparent ; in outline they may be rounded, cubical, polyhedral, prismatic, cylindrical, tabular, stellate, and of many other forms.* When the cells are bounded by plane surfaces, generally, but not always, the end planes lie at right angles to the longer axis of the cells.

* Unfortunately, the terms parenchyma and parenchymatous have often been restricted in meaning to tissues composed of cells whose three dimensions are equal.

This tissue makes up the whole of the substance of many of the lower plants. In the higher plants the essential portions of the assimilative (green), vegetative (growing), and reproductive parts are composed of parenchyma.

Instructive examples of parenchyma may be obtained in the growing ends of shoots (Fig. 53) and in the pith of Dicotyledons, in the ends of young roots—*e. g.*, of Indian corn—in the green pulp of leaves, in the pulp of fleshy fruits, and in the substance of young embryos.

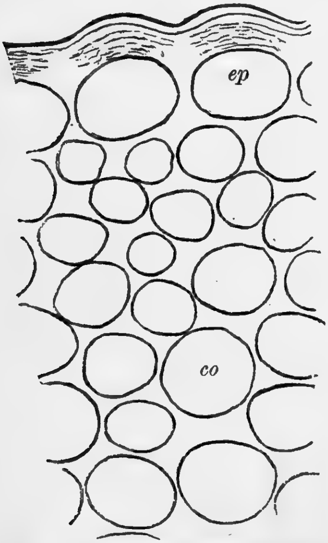


Fig. 54.—Transverse section of collenchyma (*co*) of the stem of *Echinocystis lobata*, wet with water, and the angles greatly swollen. *ep*, epidermis, with thickened outer wall. × 700. From a drawing by J. C. Arthur.

100.—Collenchyma. The cells of this tissue are elongated, usually prismatic, and their transverse walls are most frequently horizontal, rarely inclined. With few exceptions* there are no intercellular spaces. The walls are greatly thickened along their longitudinal angles, while the remaining parts are thin (Fig. 21, p. 30). The cells contain chlorophyll, and retain the power of fission.† Wet specimens show by transmitted light a characteristic bluish white lustre (Figs. 54 and 55).

Collenchyma is found beneath the epidermis of Dicotyledons (and some ferns), usually as a mass of considerable thickness, and is doubtless developed from parenchyma for the purpose of giving support and strength to the epidermis.

* In the collenchyma of *Silphium perfoliatum* there are many longitudinal intercellular spaces of various sizes; in *Ipomœa purpurea* there are minute ones.

† De Bary states that collenchyma-cells are capable of fission. "Vergleichende Anatomie der Vegetationsorgane der Phanerogamen und Farne," p. 126.

(*a*) Collenchyma may be studied in the stems, petioles, and leaf-ribs of herbaceous Dicotyledons—*e.g.*, in species of *Silphium, Rheum, Rumex, Chenopodium*—in many *Labiatæ, Solanaceæ, Begoniaceæ, Cucurbitaceæ*, and many others; also in the petioles of the water-lily and young stems of the elder.

(*b*) Upon soaking in water, or upon treatment with nitric or sulphuric acid, the thickened angles become greatly swollen.

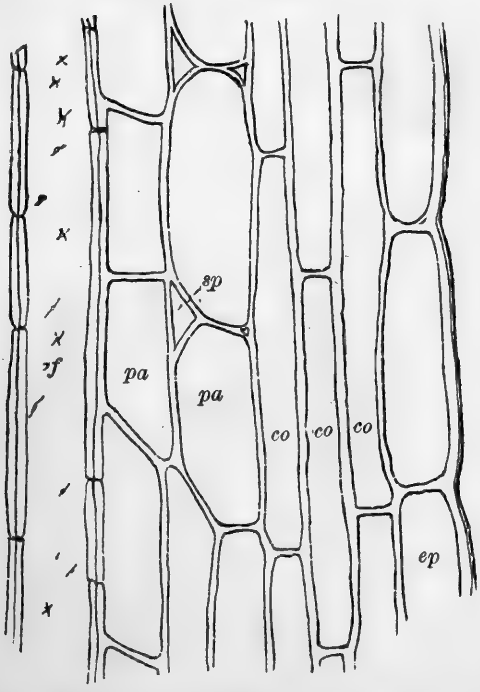


Fig. 55.—Longitudinal radial section of stem of *Echinocystis lobata*. *ep*, epidermis; *co*, collenchyma; *pa*, parenchyma; *f*. a single wood fibre, marked with "crossed" (*i.e.*, twisted) pits; *sp*, intercellular spaces. × 500. From a drawing by J. C. Arthur.

(*c*) Upon treatment with Schultz's Solution the thickened angles are colored light blue.

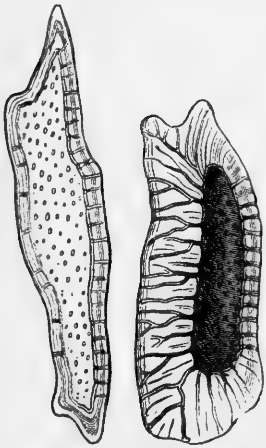
(*d*) Upon slight warming in a solution of potash, and then treating with a solution of iodine in potassium iodide, the thickened angles become colored dark blue.

101.—Sclerenchyma. In many plants the hard parts are composed of cells whose walls are thickened, often to a very

considerable extent. The cells are usually short, but in some cases they are greatly elongated; they are sometimes regular in outline, but more frequently they are extremely irregular. They do not contain chlorophyll, but in some cases at least (*e.g.*, in the sclerenchyma-cells in the pith of apple-twigs) they contain starch.

Sclerenchyma occurs in Bryophytes, Pteridophytes, and Phanerogams.

(*a*) Good specimens of sclerenchyma may be obtained for study by making longitudinal sections of the rhizome of *Pteris aquilina*, in



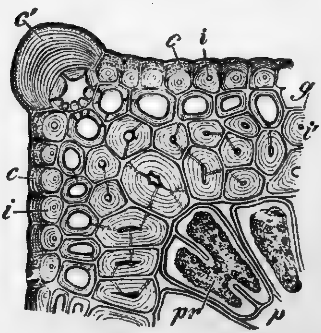


FIG. 56*B*. FIG. 56*A*. FIG. 57.

Fig. 56.—Two sclerenchyma-cells from the hypoderma of the rhizome of *Pteris aquilina*, isolated by Schulze's maceration. *A*, a very thick-walled cell, with branching pits; *B*, a cell with walls less thickened—the wall of the opposite side of the cell is seen to be filled with numerous pits. × 500.—After Sachs.

Fig. 57.—Margin of leaf of *Pinus pinaster*, transverse section. *c*, cuticularized layer of outer wall of epidermis; *i*, inner non-cuticularized layer; *c'*, thickened outer wall of marginal cell; *g*, *i'*, hypoderma of elongated sclerenchyma; *p*, chlorophyll-bearing parenchyma; *pr*, contracted protoplasmic contents. × 800.—After Sachs.

which it occurs as a thick hypodermal mass; by boiling in potassium chlorate and nitric acid (Schulze's maceration) the cells may be completely isolated (Fig. 56, *A* and *B*).

(*b*) The cells of the medullary rays of woody Dicotyledons—*e.g.*, *Acer, Pirus, Ostrya, Liriodendron*, etc.—are generally thick-walled when old, and in this state must be classed as sclerenchyma.

(*c*) The hypoderma of the leaves of pines consists of elongated sclerenchyma-cells, which at first sight might easily be mistaken for bast fibres (Fig. 57, *g*, *i*). The hypoderma of many other plants appears to be of a similar nature.

(*d*) The hard tissues of nuts and of stone fruits furnish excellent examples of short and very thick-walled sclerenchyma-cells. In the hickory nut (*Carya alba*) the cells (Figs. 58 and 59) are not more than

Fig. 58.

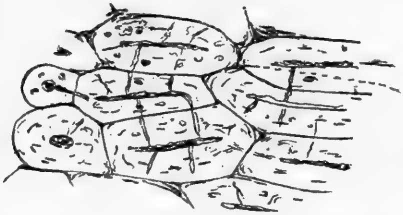


Fig. 59.

Fig. 58. — Sclerenchyma-cells of the shell (endocarp) of the hickory-nut (*Carya alba*), taken parallel to the surface of the nut. × 400.

Fig. 59.—Sclerenchyma-cells of the shell (endocarp) of the hickory-nut (*Carya alba*), taken at right-angles to the surface of the nut. × 400.

two or three times as long as broad, and the thickening is so great as almost entirely to obliterate their cavities; the thickened walls are

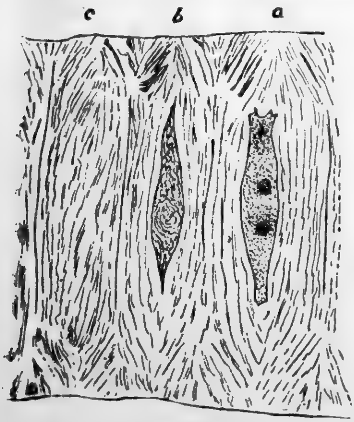


Fig. 60.

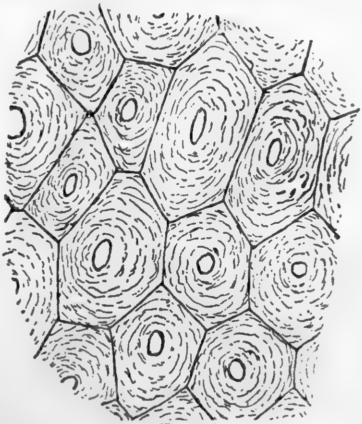


Fig. 61.

Fig. 60.—Sclerenchyma-cells of the seed-coat of *Echinocystis lobata*, from a section at right angles to the surface of the seed; *a*, a cell cut directly through its centre, showing the whole of the cavity—the three dark spots are probably oil; *b*, a cell cut through at one side of the middle; *c*, a cell whose cavity was not cut into in making the section. × 250. From a drawing by J. C. Arthur.

Fig. 61.—Sclerenchyma-cells of the seed-coat of *Echinocystis lobata*, from a section parallel to the surface of the seed. × 250. From a drawing by J. C. Arthur.

pierced by many deep pits. The cells are arranged with their longer axes perpendicular to the surface of the nut, and are very closely packed together.

(*e*) The seed-coat of *Echinocystis lobata* is composed almost entirely of sclerenchyma (Fig. 60). The cell-walls are greatly thickened, and the cells are very closely packed together, so much so that all are sharply prismatic (Fig. 61).

102.—Fibrous Tissue. This is composed of elongated, thick-walled, and generally fusiform elements, the fibres (Figs. 62 and 63), whose walls are usually marked with simple or sometimes bordered pits. These elements in cross-section are rarely square or round, but most generally three to many-sided. They are found in, or in connection with, the fibro-vascular bundles of Pteridophytes and Phanerogams, and give strength and hardness to their stems and leaves.

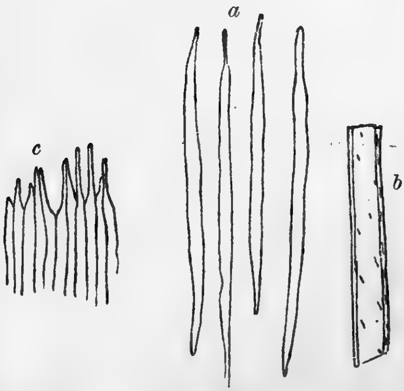


FIG. 62.

FIG. 63.

Fig. 62.—Wood fibres of *Acer dasycarpum*, isolated by Schulze's maceration. *a*, four fibres, × 95; *b*, a portion of a fibre, × 230, showing the diagonally placed elongated pits; *c*, the ends of eleven united fibres, × 95.

Fig. 63.—Bast fibres of *Acer dasycarpum*, isolated by Schulze's maceration. *a*, a fibre, × 95; *b*, a portion of a fibre, × 230, showing the much-thickened wall.

Two varieties of fibrous tissue may be distinguished, viz., (1) Bast (Fig. 63), and (2) Wood (Fig. 62). The fibres of the former are usually thicker walled, more flexible, and of greater length than those of the latter. In both forms the fibres are sometimes observed to be partitioned.*

* These partitions have generally been considered as formed subsequently to the fibres; but it may well be questioned whether, in some

To examine fibrous tissue it is only necessary to make thin longitudinal slices of the stems of woody plants—*e.g.*, *Acer*, *Pirus*, etc.—and to heat for a minute or less in nitric acid and potassium chlorate. The

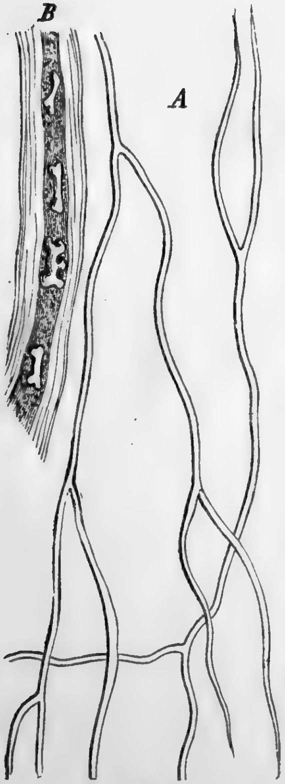


Fig. 64.

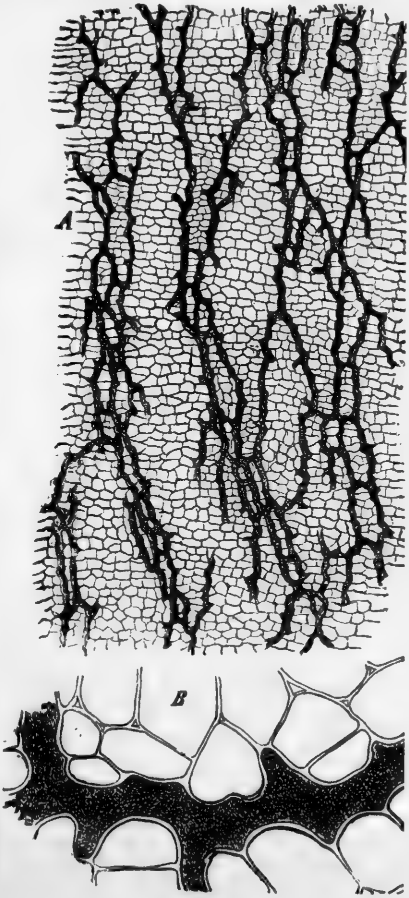


Fig. 65.

Fig. 64.—Laticiferous tubes from *Euphorbia*. *A*, moderately magnified; *B*, more highly magnified, and showing the bone-shaped or dumb-bell-shaped starch grains.—After Sachs.

Fig. 65.—Laticiferous vessels of *Scorzonera hispanica*. *A*, a transverse section of the phloëm of the root; *B*, the same more highly magnified.—After Sachs.

fibres may now be separated under a dissecting microscope, or the

---

cases at least, the fibres are not cell-derivatives, and the partitions the persistent walls of the original component cells.

specimens may be transferred to a glass slide and dissected by tapping gently upon the centre of the cover-glass.

103.—Laticiferous Tissue. In many orders of Phanerogams tissues are found whose component elements contain a milky or colored fluid—the latex. To these, although varying greatly in structure and position, the general name of Laticiferous tissues has been given. For the sake of simplicity two general forms may be distinguished: (1) that *composed of simple or branching elements* (Fig. 64), which are scattered through the other tissues. As found in *Euphorbiaceæ*, where they occur in parenchyma, they are somewhat simply branched, and have very thick walls (Fig. 64, *B*); in other orders they are thin walled and are sometimes inclined to anastomose. From their position it is quite certain that the elements of this form of laticiferous tissue frequently replace bast fibres. In such cases they are said to be metamorphosed bast fibres;* in other cases, however, they appear not to be of this nature, but to arise from the parenchyma by the absorption of the horizontal partition-walls.†

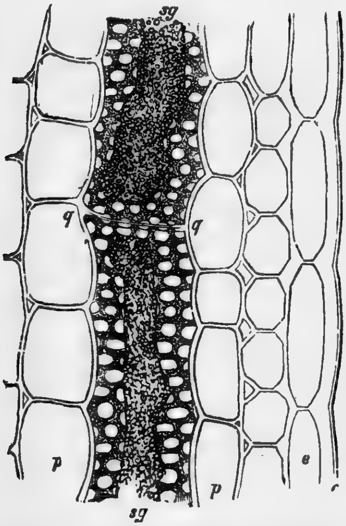


Fig. 66.—Laticiferous cells of the onion, from a longitudinal section of a scale of the bulb. *e*, epidermis with cuticle *c*; *p*, parenchyma; *sg*, coagulated contents of laticiferous cells, contracted so as to show the porous walls; *q*, *q*, transverse wall.—After Sachs.

* There is an objection to the word metamorphosed in this connection, as it does not exactly express the relation between the laticiferous elements and the bast fibres. It must not be understood that the former are made by a transformation of the *formed* bast fibres; the relation is rather that they develop from what under other circumstances would have developed into bast fibres. We may express the relation by saying that laticiferous elements and bast fibres are closely related sister elements.

† "According to Hanstein, it is probable that in some Aroideæ vessels

(2.) The other form is that composed of *reticulately anastomosing vessels.* Here the tissue is the result of the fusion of great numbers of short cells. The walls are thin and often irregular in outline. In *Cichoriaceæ* this form of laticiferous tissue is very perfectly developed as a constituent part of the phloëm portion of the fibro-vascular bundles (Fig. 65, *A* and *B*).

(*a*). Laticiferous tissue has not yet been shown to contain either protoplasm or nucleus.* The latex is an emulsion of several substances, some of which, as caoutchouc (India-rubber), gutta-percha, and opium, are of great economic importance. In some cases, as in *Euphorbia*, grains of starch are contained in the latex (Fig. 64, *B*).

(*b*) The chemical composition of latex is shown by the following analyses, as given by De Bary: †

Latex of *Hevea Guianensis*, as determined by Faraday:

Water with an organic acid	56.3	per cent.
Caoutchouc	31.7	" "
Albumen	1.9	" "
Bitter nitrogenous matter, with wax	7.1	" "
Residue soluble in H_2O, but insoluble in alcohol.	2.9	" "
	99 9	

Latex of *Galactodendron utile*, as determined by Heintz:

Water	57.3	per cent.
Albumen	0.4	" "
Wax ($C_{35}H_{66}O_3$)	5.8	" "
Resin ($C_{35}H_{58}O_2$)	31.4	" "
Gum and sugar	4.7	" "
Ash	0.4	" "
	100.	

Latex of *Euphorbia cyparissias*, determined by Weiss and Wiesner:

Water	72.1	per cent.
Resin	15.7	" "
Gum	3 6	" "
Sugar and extractive substances	4.1	" "
Albumen	0.1	" "
Ash	0.9	" "
	96.5	

of the xylem assume the form and function of laticiferous vessels.", Sachs' "Text-Book of Botany," English edition, p. 110.

* The latex of some Cichoriaceæ coagulates much like protoplasm; possibly further investigation will show it to be present.

† "Anatomie der Vegetationsorgane," etc., p. 194.

(*c*) Examples of the simpler forms of laticiferous tissue may be obtained for study from *Euphorbiaceæ, Urticaceæ, Asclepiadaceæ, Apocynaceæ.* Forms less simple occur in *Araceæ,* and in the maple ; in the last-mentioned they appear to replace the sieve-vessels. Related to these again are the peculiar milk-vessels of the onion (Fig. 66), which consist of elongated cells separated by thin or perforated septa.

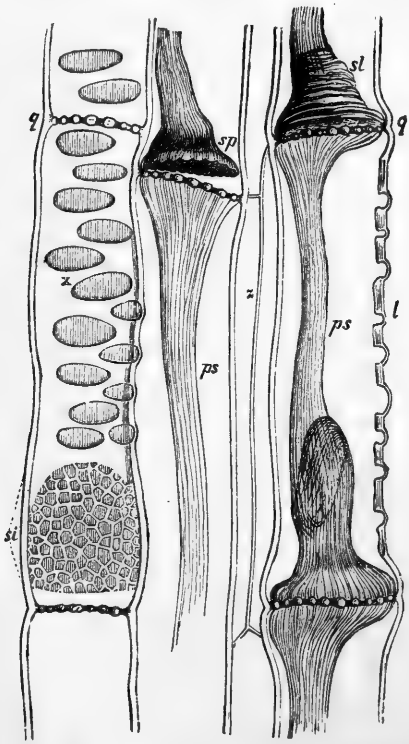


Fig. 67. — Longitudinal section through the sieve tissue of *Cucurbita Pepo.* *q, q,* section of transverse sieve-plates ; *si,* lateral sieve-plate ; *x,* thin places in wall ; *l,* the same seen in section ; *ps,* protoplasmic contents contracted by the alcohol in which the specimens were soaked ; *sp,* protoplasm lifted off from the sieve-plate by contraction ; *sl,* protoplasm still in contact with the sieve-plate ; *z,* parenchyma between sieve tubes. × 550. — After Sachs.

(*d*) The more complex or reticulated forms of laticiferous tissue occur in *Cichoriaceæ, Campanulaceæ, Lobeliaceæ, Convolvulaceæ, Papaveraceæ.*

(*e*) By heating thin sections of any of the foregoing plants in a dilute solution of potash the laticiferous tissues may be readily isolated for study.

(*f*) The walls of the laticiferous elements are always rich in water, and are composed of cellulose, as may be shown by the blue coloration which follows treatment with Schultz's Solution.

104.—Sieve Tissue. As found in the Angiosperms this tissue is made up of sieve ducts and the so-called latticed cells. The former (the sieve ducts) consist of soft, not lignified, colorless tubes of rather wide diameter, having at long intervals horizontal or obliquely placed perforated septa. The lateral walls are also perforated in restricted areas, called sieve discs, and through these perforations and those in the horizontal walls the protoplasmic contents of the contiguous cells freely unite (Figs. 67 and 68). In many plants the sieve discs close up in winter by a thickening of their substance (Fig. 69).

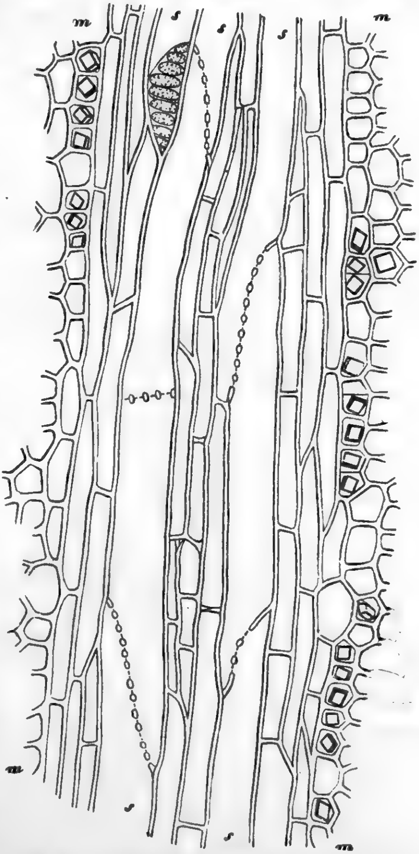


Fig. 68.—Longitudinal tangential section of the young bark of the grape (*Vitis vinifera*), taken in the beginning of July. *s*, *s*, sieve tubes, with sections of the transverse plates—in the left-hand sieve tube, at the top of the figure a lateral plate is shown; *m*, *m*, medullary rays, with crystals in some of the cells—between the sieve tubes themselves, and between them and the medullary rays, are masses of parenchyma (phloëm parenchyma). × 145.—After De Bary.

The tissue composed of these ducts is generally loose, and more or less intermingled with parenchyma; in some cases even single ducts run longitudinally through the substance of other tissues. In the form described above it is found only as one of the components of the phloëm portion of the fibro-vascular bundle.

105. — The so-called *latticed cells* are probably to be

regarded as undeveloped sieve ducts, and hence the tissue they form may be included under sieve tissue. Latticed cells are thin-walled and elongated; they differ from true sieve ducts principally in being of less diameter, and in having the markings but not the perforations of sieve discs. Both of these differences are such as might be looked for in undeveloped sieve tissue.

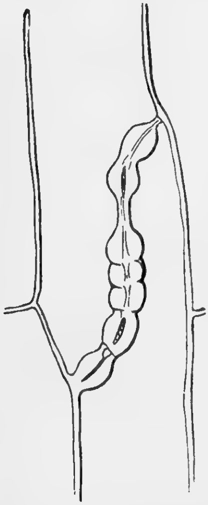


Fig. 69. — Longitudinal tangential section of the young bark of the grape, (*Vitis vinifera*), taken in winter; the sieve plate is closed up by the thickening of its substance. × 400.—After De Bary.

106.—In the corresponding parts of the vascular bundles of Gymnosperms and Pteridophytes a sieve tissue is found which differs somewhat from that in Angiosperms. In Gymnosperms the sieve discs, which are of irregular outline, occur abundantly upon the oblique ends and radial faces of the broad tubes (Fig. 70). In Pteridophytes the tubes have varying forms; in *Equisetum* and *Ophioglossum* they are prismatic, with numerous horizontal but not vertical sieve discs; in *Pteris* and many other ferns they have pointed extremities, and are greatly elongated, bearing the sieve discs upon their sides (Fig. 71). In the larger *Lycopodiaceæ* the sieve tubes are prismatic and of great length; in the smaller species there are tissue elements destitute of sieve discs, but which are otherwise, including position in the stem, exactly like the sieve ducts of the larger species.

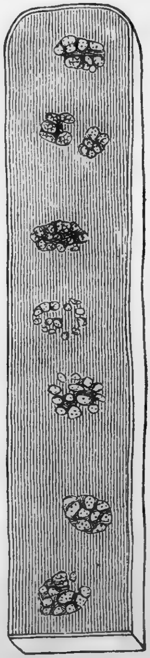


Fig. 70. — Radial view of the end of a sieve tube of *Sequoia gigantea*, taken from the bark of an old stem; the sieve plates are placed laterally and are composed of many little punctured areas grouped together irregularly. × 375.—After De Bary.

(*a*) **Good specimens of sieve tissue may be obtained for study by making longitudinal sections of the stems of *Cucurbita, Cucumis,***

Echinocystis, Ecbalium, Vitis, Bignonia, and *Calamus Rotang;* also *Abies pectinata, Larix, Juniperus, Sequoia,* and *Ginkgo;* also *Pteris, Osmunda, Equisetum,* and *Lycopodium.*

(*b*) By making repeated horizontal sections the horizontal sieve discs may be found and studied.

(*c*) Alcoholic specimens afford much more satisfactory results than fresh ones; especially is this the case with the more succulent plants.

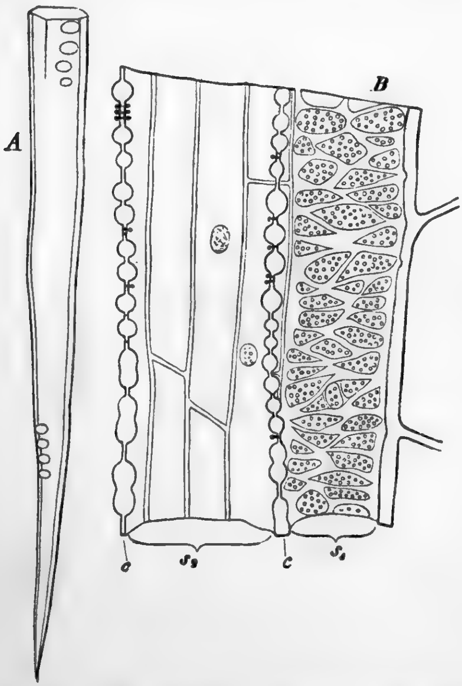


Fig. 71.—Sieve tissue of *Pteris aquilina.* *A*, end of a sieve tube isolated by maceration; *B*, portions of two tubes seen in vertical section; in s' the sieve plates are seen in front view; at *c, c*, they are seen in section; the tube s^2 has sieve plates on its right and left walls, but none on its further wall, which is in contact with parenchyma-cells; two of the latter are seen to have nuclei in them. × 375.—After De Bary.

107.—Tracheary Tissue. Under this head are to be grouped those vessels which, while differing considerably in the details, agree in having thickened walls, which are perforated at the places where similar vessels touch each other. The

thickening, and as a consequence the perforations, are of various kinds, but generally there is a tendency in the former to the production of spiral bands; this is more or less evident even when the bands form a network. The transverse partitions, which may be horizontal or oblique, are in some cases perforated with small openings, in others they are almost or entirely absorbed. The diameter of the vessels is usually considerably greater than that of the surrounding cells and elements of other tissues, and this alone in many cases may serve to distinguish them. When young they of course contain protoplasm, but as they become older this disappears, and they then contain air.

108.—Tracheary tissue is found only in Pteridophytes

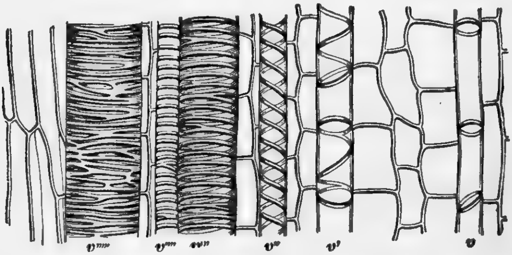


Fig. 72.—Longitudinal section of a portion of the stem of *Impatiens Balsamina*. v, a ringed vessel; v', a vessel with rings and short spirals; v'', a vessel with two spirals; v''' and v'''', vessels with branching spirals; v''''', a vessel with irregular thickenings, forming the reticulated vessel.—After Duchartre.

and Phanerogams. The principal varieties of vessels found in tracheary tissues are the following:

(1.) *Spiral Vessels*, which are usually long, with fusiform extremities; their walls are thickened in a spiral manner with one or more simple or branched bands or fibres (Fig. 72, v'', v''', v''''). This form may be regarded as the typical form of the vessels of tracheary tissue. In most cases the direction of the spiral is from right to left.* It is frequently in one direction in the earlier formed spirals and the op-

*** Right to left, in speaking of these spirals, as also in describing the twining of certain climbing plants, is passing up and around in the direction of the hands of a watch. Left to right is of course up and around opposite to the hands of a watch.**

posite in those formed later; while in interrupted spirals both directions occur in the same vessel. *Ringed* and *reticulated* vessels are opposite modifications of the spiral form;

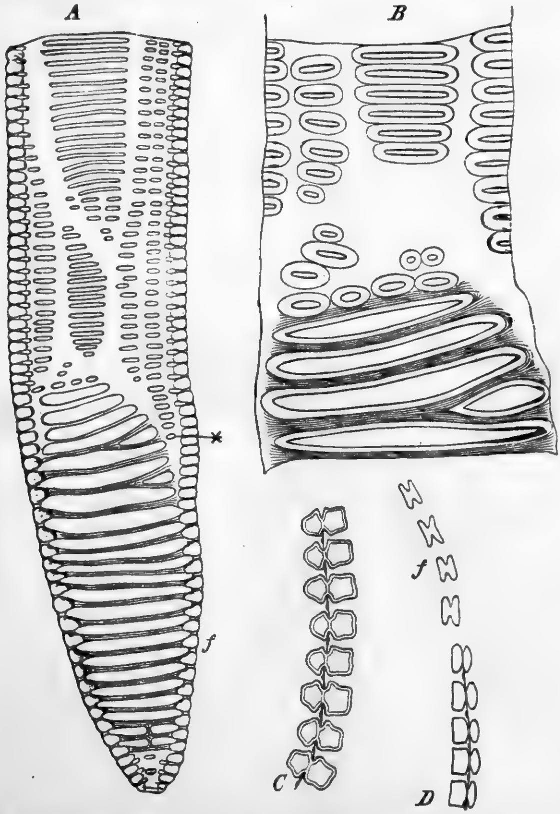


Fig. 73.—Scalariform vessels of the rhizoma of *Pteris aquilina*. *A*, longitudinal section of an end (about one third of the whole) of a short vessel; *f*, the fusiform extremity, with long pits placed transversely; *B*, a small portion of *A*, taken from *x*, and much more highly magnified; *C*, a longitudinal section of a portion of the side wall between two vessels; *D*, a similar section through the inclined end wall (*A*, *f*); in the upper part of *D*, at *f* the wall between the thickening ridges is broken through. *A*, × 142; the others × 375.—After De Bary.

the first are due to an under-development of the thickening forces in the young vessels, resulting in the production here and there of isolated rings (Fig. 72, *v*); reticulated vessels are due, on the contrary, to an over-development, which

gives rise to a complex branching and anastomosing of the spirals (Fig. 72, v''''').

(2.) *Scalariform vessels.* These are prismatic vessels whose walls are thickened in such a way as to form transverse ridges, as described in paragraph 32, page 28. They are wide in transverse diameter and their extremities are fusiform or truncate (Fig. 73).

(3.) *Pitted Vessels.* The walls of these vessels are thickened in such a way as to give rise to pits and dots, as described in paragraph 31, page 26. The vessels are usually of wide diameter; in some forms they are crossed at frequent intervals by per-

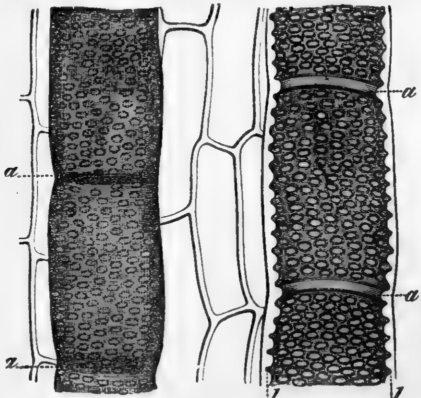


FIG. 74.

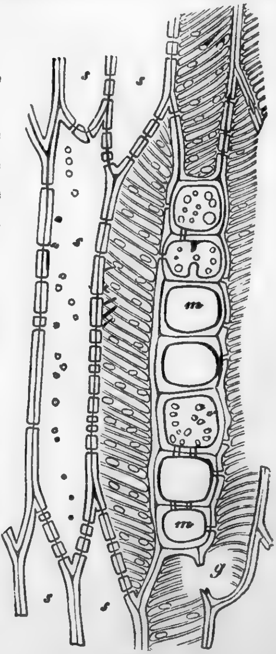


FIG. 75.

Fig. 74.—Pitted vessels of ***Aristolochia sipho***, from a longitudinal section of the stem; the vessel on the right is seen in section, that on the left from without; *a*, *a*, rings, which are remnants of the original transverse partitions; *b*, *b*, sections of the walls; between the vessels are parenchyma-cells, highly magnified.—After Duchartre.

Fig. 75.—Tracheïdes of *Cytisus laburnum*, from a longitudinal tangential section of the stem; *m*, *m*, a cross-section of a medullary ray; in three of the cells the pitted partitions are seen; the medullary ray is surrounded by tracheïdes, which are spirally marked and sparingly pitted; at *g*, two tracheïdes have fused by the breaking of the wall; *s*, *s*, slightly modified cambium-cells. × 375.—After De Bary.

forated horizontal or inclined septa (Fig. 74); in other forms they have fusiform extremities.

(4.) *Tracheïdes.* These consist for the most part of single closed cells, or of elements which closely resemble cells;

otherwise they possess the characters of vessels. In one form, as in the so-called wood-cells of Gymnosperms (see paragraph 30, page 25) they resemble on the one hand the pitted vessels, and on the other the fibres of the wood of Angiosperms. Every gradation between these tracheïdes and the other forms of tracheary tissue occur. In another form, as in *Cytisus* and *Celtis*, the tracheïdes are shorter than in the preceding, quite regular in their form, and with tapering extremities (Fig. 75). Their walls are but slightly thickened, and are marked with spirals and pits. When the wall between two contiguous cells breaks through or becomes absorbed the close relation of such tracheïdes to spiral vessels is readily seen.

Tracheïdes may be regarded as composing a less differentiated form of tissue, related on the one hand to true tracheary tissue and on the other to fibrous tissue.

(*a*) Specimens of spiral vessels with the spirals passing from right to left may be obtained by making longitudinal sections of the stems of *Malva rotundifolia, Impatiens Balsamina.* and many other plants. If the thin slices are macerated in nitric acid and potassium chlorate the structure may be studied to still better advantage. The spirals in the vessels of *Pinus sylvestris* pass from left to right; they may be examined in longitudinal sections of the leaves or young twigs. The stems of *Vitis vinifera, Berberis vulgaris, Bignonia capreolata,* and *Artemisia abrotanum* furnish examples of vessels, the first formed of which have their spirals running from right to left and the later ones from left to right. Interrupted spirals showing the two directions may be found in stems of *Cucurbita.*

(*b*) Examples of scalariform vessels may be obtained with the greatest ease from the rhizomes of ferns—*e.g.*, of *Pteris;* it may also be obtained from many Dicotyledons—*e.g.*, the stems of *Vitis.*

(*c*) Fine specimens of pitted vessels may be studied in longitudinal sections of many kinds of wood—*e.g.*, *Pirus, Quercus,* and *Liriodendron;* among herbs, *Impatiens* and *Ricinus* furnish good examples.

(*d*) In order to study the tracheïdes of the Gymnosperms thin slices of the wood—of Pinus, for example—should be heated for some time in nitric acid and potassium chlorate. By this means, after transferring to a glass slide and covering in the usual way, the tracheïdes may be easily isolated by gently tapping upon the cover-glass.

(*e*) Tracheïdes of the second form are easily studied in horizontal and longitudinal sections of the wood of *Celtis.*

§ III. The Primary Meristem.*

109.—Under this name are grouped the unformed and growing tissues found at the ends of young stems, leaves, and roots. In these parts the tissues described above (paragraphs 99 to 108) have not yet formed; they are, on the contrary, composed entirely of a mass of thin-walled, growing, and dividing cells containing an abundance of non-granular protoplasm. In the lower plants the meristem-cells do not change much in their configuration or general structure as they develop into the ordinary plant-cells; but the higher the type of plant, the greater are the changes which take place during the development of meristem into permanent tissues.

110.—In most of the plants outside of the Phanerogams the primary meristem is the result of the continually repeated division of a single mother-cell situated at the apex of the growing organ. In the simplest forms this apical cell is the terminal one of a row of cells, as in many algæ and fungi. The apical cell, in such cases, keeps on growing in length, and at the same time horizontal partitions are forming in its proximal portion. In this way long lines of cells may originate.

In the more complicated cases the segments cut off from the apical cell grow and subdivide in different planes, so as to give rise to masses of cells. The partitions which successively divide the apical cell are sometimes perpendicular to its axis, but more frequently they are oblique to it. In most mosses, for example (Fig. 76), the apical cell is a triangular, convex-based pyramid, whose apex is its proximal portion. The successive segments are cut off from the apical cell by alternate partitions parallel to its sides, thus giving rise to three longitudinal rows of cells. Most Pteridophytes have an apical cell not much different from that of the majority of mosses. In *Equisetum*, for example, it is an inverted triangular pyramid, having a convex base (Fig. 77;

* From the Greek μέρος, part, and τέμνιεν, to cut off. This tissue is sometimes called Proto-meristem.

A, side view, *B,* a section). The segments (daughter-cells) are cut off by alternating partitions parallel to the plane sides of the pyramid, as in the mosses. In some of the Bryophytes and Pteridophytes the apical cell is wedge-shaped —*i.e.,* with only two surfaces—and in such cases two instead of three rows of meristem-cells are formed.

111.—In the Phanerogams the Primary Meristem is developed from a group of cells, instead of from a single one; they therefore have no apical cell. This group of cells

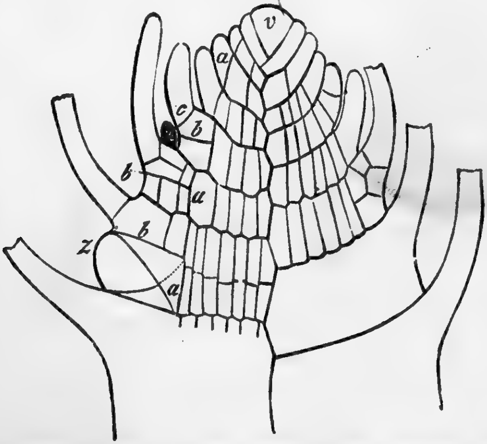


Fig. 76.—Longitudinal section of apex of stem of a moss (*Fontinalis antipyretica*). *v*, apical cell, forming segments (3 rows), each segment divided into an outer cell, *a*, and an inner one—the former develops cortex of the stem and a leaf, the latter the inner tissue of the stem; *z*, apical cell of lateral leaf-forming shoot, arising below a leaf; *c*, first cell of leaf; *b*, cells forming cortex.—After Leitgeb.

occupies approximately the same position in the organs of Phanerogams as the apical cell does in the Bryophytes and Pteridophytes; it is composed of cells which have the power of indefinite division and subdivision.

112.—The apical cell, and its actively growing daughter-cells in its immediate vicinity, or in the case of the Phanerogams the apical group of cells, with their daughter-cells, constitute the Growing Point or Vegetative Point (*Punctum vegetationis*) of the organ. When this active portion is conical in shape it is the Vegetative Cone of some authors.

(*a*) Primary Meristem tissue may be readily obtained for study by making thin longitudinal sections of the tips of growing shoots of *Equisetum, Phaseolus, Hippuris,* and the roots of *Pteris, Zea, Impatiens,* etc., or by carefully dissecting out the youngest rudiments of the leaves of many Monocotyledons.

The value of the specimen will often be increased by staining it with carmine.

(*b*) The apical cell, which may be seen in the best of the above-mentioned sections of *Equisetum* and *Pteris,* should also be studied by making extremely thin cross-sections of the apical portion of the Vegetative Cone; the triangular shape of the apical cell can thus be made out.

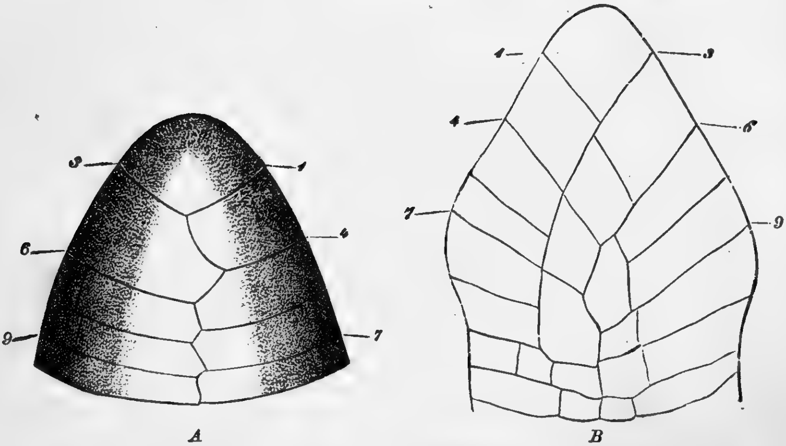


Fig 77.—The growing point of the stem of *Equisetum scirpoides. A,* seen from without, showing the apical cell at the top; the numerals 1, 3, 4, etc., indicate the order of the formation of the partitions of the apical cell; that marked 1 is the last formed, 3 the third from the last, etc.; between 4 and 7 on the right, and 6 and 9 on the left, are the partitions which form after the primary ones; *B,* a vertical section of *A.*

The simple side view of the isolated Vegetative Cone is also instructive when so prepared that it can be rotated under the microscope.

CHAPTER VII.

TISSUE SYSTEMS.

§ I.—The Differentiation of Tissues into Systems.

113.—It rarely happens that the tissues which compose the body of a plant are uniform. In the great majority of cases the cells of the Primary Meristem become differently modified, so as to give rise to several kinds of tissues. The outer cells of the plant become more or less modified into a boundary tissue, and the degree of modification has relation to its environment. Certain inner cells, or lines of cells, become modified into sclerenchyma, or some other supporting tissue (collenchyma, or fibrous tissue), and here again there is a manifest relation to the environment of the plant. Certain other inner cells, or rows of cells, become modified into tubes affording a ready means for conduction, and appear to have a relation to the physical dissociation of the organs of the higher plants, in which only they occur. Thus, in physiological terms, there may be a boundary tissue, a supporting tissue, and a conducting tissue, lying in the mass of less differentiated ground tissue.

114.—In different groups of plants the elementary tissues described in previous paragraphs (99 to 108) are aggregated in different ways, and are variously modified to form these bounding, supporting, and conducting parts of the plant. Several tissues, or varieties of tissue, are regularly united or aggregated in particular ways in each plant, constituting what may be called Groups or Systems of Tissues. A Tissue System may then be described as an aggregation of elementary tissues, forming a definite portion of the internal structure of the plant. From what has already been said, it

is clear that systems of tissue do not exist in the lowest plants, and that they reach their fullest development only in the highest orders. It is evident also that these systems have no existence in the youngest parts of plants, but that they result from a subsequent development.

115.—Many systems of tissue might be enumerated and described; but here again, as with the elementary tissues, while there are many variations, there are also many gradations, having on the one hand a tendency to give us a long list of special forms, and on the other to reduce them to one, or at most to two or three. The three systems proposed by Sachs are instructive, and will be followed here; they are: (1) the Fundamental System, which includes the mass of unmodified or slightly modified tissues found in greater or less abundance in all plants (except the lowest); (2) the Epidermal System, composed mainly of the boundary cells and their appendages (hairs, scales, stomata, etc.); (3) the Fibro-vascular System, comprising those varying aggregations of tissues which make up the string-like masses found in the organs of the higher plants.

§ II.—The Epidermal System of Tissues.

116.—This is the simplest tissue system, as it is the earliest to make its appearance, in passing from the lower forms to the higher. It is also (in general) the first to appear in the individual development of the plant. It is sometimes scarcely to be separated from the underlying mass, as in most higher Thallophytes and Bryophytes; and here it is composed of but one tissue—parenchyma—or of two or more slight variations of it. In Pteridophytes and Phanerogams, while it may be very simple in some (aquatic) plants, it frequently attains some degree of complexity, and is sharply separated from the underlying ground tissues.

117.—In the simpler epidermal structures of the Thallophytes the cells are generally darker colored, smaller, and more closely approximated than they are in the subjacent mass; in some higher fungi a boundary tissue may be easily separated as a thickish sheet, but probably in such case a

portion of the underlying mass is also removed. In many of the Thallophytes there is absolutely no differentiation of an epidermal portion.

118.—In the Bryophytes there is in general a poor epidermal development; it is composed for the most part of one or more weakly defined layers of smaller cells, which, however, pass by insensible gradations into the inner tissue mass. Here, however, the first true epidermal hairs make their appearance.

119.—In one group of the Liverworts—the *Marchantiaceæ*

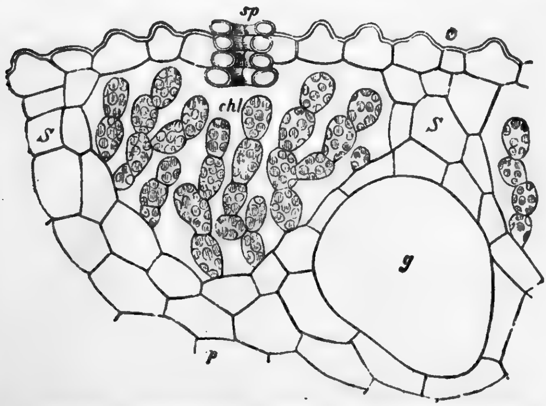


Fig. 78.—Longitudinal section of erect portion of thallus of *Marchantia polymorpha.* *o*, epidermis; *S*, walls between air-spaces, the latter filled with rows of chlorophyll-bearing cells, *chl*; *sp*, a stoma; *g*, a large parenchyma-cell. × 550.—After Sachs.

—there is an epidermal system of a high degree of perfection, and composed of epidermis proper and stomata (Fig. 78). The epidermis consists of a single layer of somewhat tabular cells arching over the air-cavities which occupy the upper surface of the plants; it is perforated here and there by stomata or breathing pores, composed of four to eight circular rows of cells placed one above the other (*sp* in the figure). These chimney-like structures originate by the division of a single cell into four or six radiating daughter-cells; in the centre of this group an intercellular pore is formed by the lateral growth of the cells (Fig. 79); and by a subsequent

horizontal division the several superimposed circular rows of cells are formed.

120.—In true mosses the sporangia possess an epidermal system which is composed of a layer of strongly cuticularized cells—the epidermis—sometimes provided with stomata. Other portions of the plant, aside from the sporangia, are destitute of a true epidermis or of stomata.

121.—The epidermal systems of Pteridophytes and Phanerogams are so much alike that they may be described together, although it must be remembered that in the latter group they are, in general, somewhat more perfect than in the former. In these groups the epidermal structures consist usually of three portions: (1) a layer of more or less modified parenchyma—the epidermis proper—bearing two other kinds of structures which develop from it, viz., (2) trichomes, and (3) stomata.

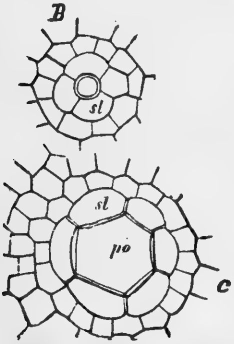


Fig. 79.—Top view of two stomata of *Marchantia polymorpha*. *B*, young stoma; *sl*, guard cells; *C*, older stoma, in which the pore or opening, *po*, is much larger; *sl*, guard-cells.—After Sachs.

122.—Epidermis. The differentiation of parenchyma in the formation of epidermis, when carried to its utmost extent, involves three different modifications of the cells, viz., (1) change of form, (2) thickening of the walls, (3) disappearance of the protoplasmic contents. These three modifications may occur in varying degrees of intensity; they may all be slight, as in many aquatic plants and in the young roots of ordinary plants; or the cells may change their form, while there may be little thickening of their walls, as in other aquatic plants, and some land plants which live in damp and shady places; or on the other hand, the change of form of the cells may be but little, while their walls may have greatly thickened, resulting in a disappearance of their protoplasm, as may be seen in parts of some land plants which grow slowly and uniformly. When the differentiation of epidermis is considerable, it can usually be readily removed as a thin transparent sheet of colorless cells.

123.—The change in the form of the epidermal cells is due to the mode of growth of the organ of which they form a part; the lateral and longitudinal growth of an organ causes a corresponding extension and consequent flattening of the cells; if the growth has been mainly in one direction, as in the leaves of many Monocotyledons, and the young shoots of many Dicotyledons, or if the growth in two directions has been regular and uniform, as in the leaves of some Dicotyledons, the cells are quite regular in outline; where, however, the growth is not uniform the cells become irregular, often extremely so (Fig. 89, page 100).

124.—The thickening of the walls is greatest in those plants and parts of plants which are most exposed to the drying effects of the atmosphere. It consists of a thickening of the outer walls, and frequently of the lateral ones also. The outer portion of the thickened walls is cuticularized, and this, by a subsequent stratification and lamellation, is separated as a continuous pellicle, the so-called cuticle.

125.—The cuticle extends uninterruptedly over the cells, and may be readily distinguished from the other portions of the outer epidermal walls. It is insoluble in concentrated sulphuric acid, but may be dissolved in boiling caustic potash. Treated with iodine it turns a yellow or yellowish brown color. A waxy or resinous matter is frequently developed upon the surface of the cuticle, constituting what is called the *bloom* of some leaves and fruits. De Bary* distinguishes four kinds of waxy coating, as follows: (1) continuous layers or incrustations of wax—*e.g.*, on the leaves and stems of purslane, the leaves of *Fuchsia*, yew, the stems of the wax palms (*Ceroxylon*), etc.; (2) coatings composed of multitudes of minute rods placed vertically side by side upon the cuticle—*e.g.*, on the stems of sugar cane, *Coix lachryma*, and some other grasses; (3) coatings made up of minute rounded grains in a single layer—*e.g.*, on the leaves of the cabbage, onion, tulip, clove-pink (*Dianthus*

---

* "Vergleichende Anatomie der Vegetationsorgane der Phanerogamen und Farne," 1877, p. 87, where figures of several of these kinds are given.

Caryophyllus), etc.; (4) coatings of minute needles or grains irregularly covering the surface with several layers—*e.g.*, on the leaves of *Eucalyptus globulus*, rye, etc.

126.—The protoplasm of the epidermal cells generally disappears in those cases where there is much thickening of the walls; it is always present in young plants and parts of plants; it is also frequently present in older portions, which are not so much exposed to the drying action of the atmosphere, as in roots, and the leaves and shoots of aquatic plants, and of those growing in humid places. In few cases, however, are granular protoplasmic bodies (*e.g.*, chlorophyll) present in epidermal cells.*

127.—While the epidermis always consists at first of but one layer of cells, it may become split into two or more layers by subsequent divisions parallel to its surface. These layers may resemble the outer one and have their walls thickened, as in the leaves of the Oleander, or they may consist of thin-walled cells with watery contents (constituting the so-called Aqueous Tissue), as in the leaves of Ficus and Begonia.

(*a*) Epidermis may be studied with comparatively little difficulty. In many cases it may be stripped off in thin sheets and mounted in the usual way; such preparations, with thin cross-sections (which are readily made by placing a piece of leaf between pieces of elder pith), are sufficient, in most cases, to give a good knowledge of the structure. The leaves of many *Liliaceæ* (hyacinths, lilies, etc.) and *Gramineæ* may be examined for regular cells, and those of many Dicotyledons, as balsams, primroses, and fuchsias, for irregular ones.

(*b*) Thickened epidermal walls may be found in leaves of a hard texture, as those of the pines, holly, oleander, mistletoe, many *Compositæ*, and in the stems of many *Cactaceæ*. The stratification of the thickened walls may be brought out in the cross-sections by heating in a solution of potash.

(*c*) A series of specimens of the epidermis, taken from leaves of all ages, from their youngest and smallest rudiments in the bud up to full-grown ones, is instructive.

---

* In the leaves of *Primula sinensis*, grown in the green-house, the epidermal cells contain many chlorophyll-bodies; the leaves of Fuchsias, under similar conditions, possess a few chlorophyll-bodies in the epidermal layer.

128.—Trichomes. Under this term are to be included the outgrowths which arise from the epidermis ; they may have the form of hairs, scales, glands, bristles, prickles, etc., and may be composed of single cells, or of masses of cells.

They originate mostly from the growth of single epidermal cells,* and on their first appearance consist of slightly en-

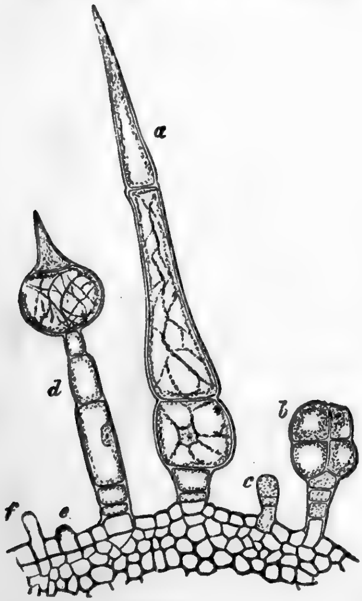


FIG. 80.

FIG. 81.

Fig. 80.—Transverse section of epidermis and underlying tissue of ovary of *Cucurbita*. *a*, hair of a row of cells ; *b* and *d*, glandular hairs of different ages ; *e*, *f*, *c*, hairs in the youngest stages of their development. × 100.—After Prantl.

Fig. 81.—A seedling mustard plant with its single root clothed with root-hairs : the newest (lowermost) portion of the root is not yet provided with root-hairs.

larged and protruding cells (Fig. 80, *e*, *f*, *c*). These may elongate and form single-celled hairs, which may be simple or variously branched. The most important of these hairs are those which clothe so abundantly the young roots of most of the higher plants, and to which the name of Root-hairs

* It is probable that the common statement that trichomes always develop from single cells must be modified.

has been applied (Fig. 81). These are composed of single cells, which have very thin and delicate walls (Fig. 82), and are the active agents in the absorption of nutritive matters for the plant.

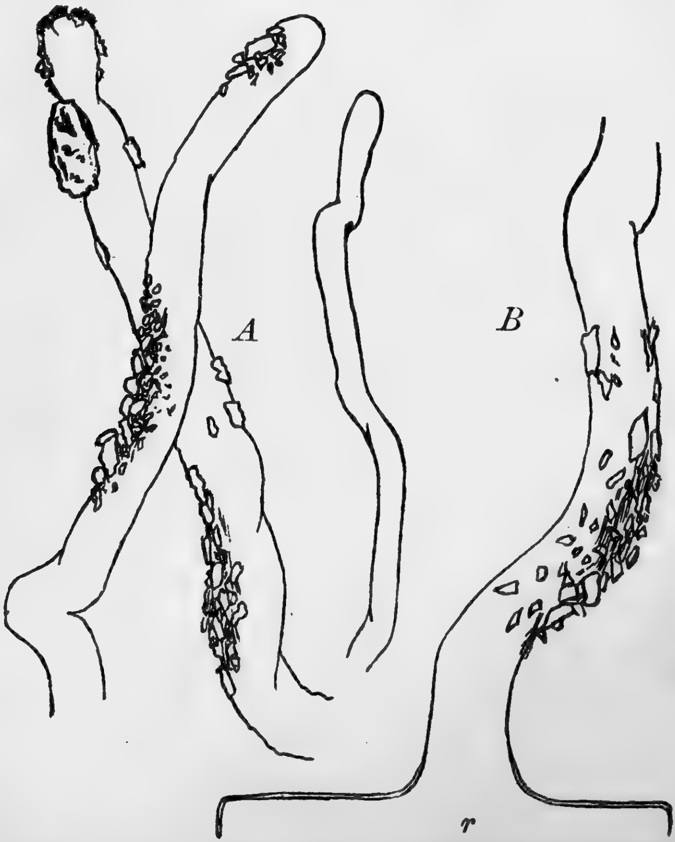


Fig. 82.—Root-hairs of a seedling rye plant. *A*, the ends of three hairs, one much smaller than the others; the larger ones have particles of sand adhering to and imbedded in their walls; *B*, the base of a hair growing from the root-cell, *r*. × 900.

129.—In the development of the hairs on aerial parts of plants it frequently happens that the terminal cell becomes changed into a secreting cell, in which gummy, resinous, or other substances are produced; sometimes several terminal

cells are so transformed into a secreting organ. The secretion appears as a rounded pustule, partly surrounding the secreting cell (Figs. 83 to 87), and which is removed upon the slightest touch. Trichomes of this nature are called glandular hairs; they are exceedingly variable in form, and are not infrequently short and depressed, when they are known as surface glands, or glandular scales (Fig. 87).

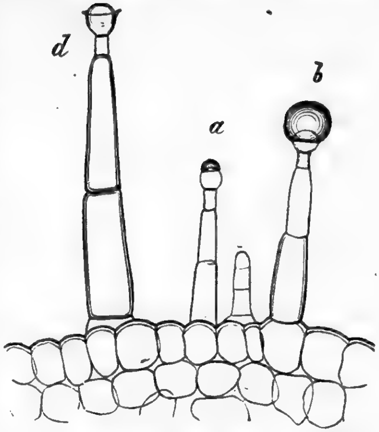


Fig. 83.—Glandular hairs from the petiole of *Primula sinensis*, in several stages of development. *a*, the beginning of the secretion in the terminal cell; *b*, hair with a large mass of secreted matter; *d*, an old hair after the removal of the secreted matter. × 142.—After De Bary.

(*a*) Trichomes are, in general, easy objects of study. In many cases they may be simply scraped off and mounted in alcohol, or in a solution of potash

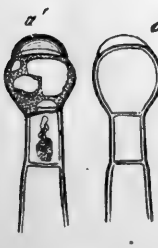


FIG. 84.

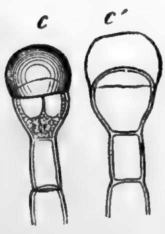


FIG. 85.

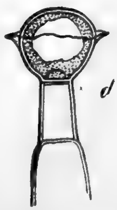


FIG. 86.

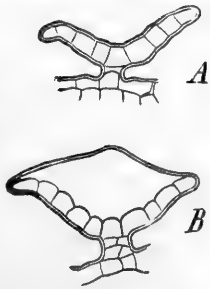


FIG. 87.

Fig. 84.—*a′*, the cell *a* of Fig. 83 more highly magnified; *a″* the same after removal of the secretion by treatment with alcohol. × 375.—After De Bary.

Fig. 85.—*c*, end of a hair with large mass of secreted matter; *c′*, the same after treatment with alcohol. × 375.—After De Bary.

Fig. 86.—The end of the hair *d*, in Fig. 83, more highly magnified, showing the fragments of the secretion pustule surrounding the terminal cell, which still contains protoplasm. × 375.—After De Bary.

Fig. 87.—Glandular scale from the hop. *A*, in its young stage; *B*, the same some time afterward—the secretion from the cells has pushed out the cuticle and filled the space between it and the cells (in the specimen from which these were drawn the secretion was removed by solution in alcohol). × 142.—After De Bary.

after wetting them with alcohol to free them from entangled and enclosed air.

(*b*) One-celled simple hairs may be obtained from the vegetative organs of species of *Œnothera* and *Brassica* and many grasses—*e.g.*, species of *Panicum*—and from the seeds of the cotton plant; the last constitute the "cotton" of commerce.

(*c*) Many-celled simple hairs occur on the filaments of *Tradescantia*, on leaves of the Primrose, *Ageratum*, *Erigeron Canadense*, pumpkin, and very many others.

(*d*) Branched one-celled hairs occur in *Capsella*, *Draba*, *Sisymbryum*, *Alyssum*, and many other *Cruciferæ*.

(*e*) Branched many-celled hairs may be found on the Mullein and Ivy.

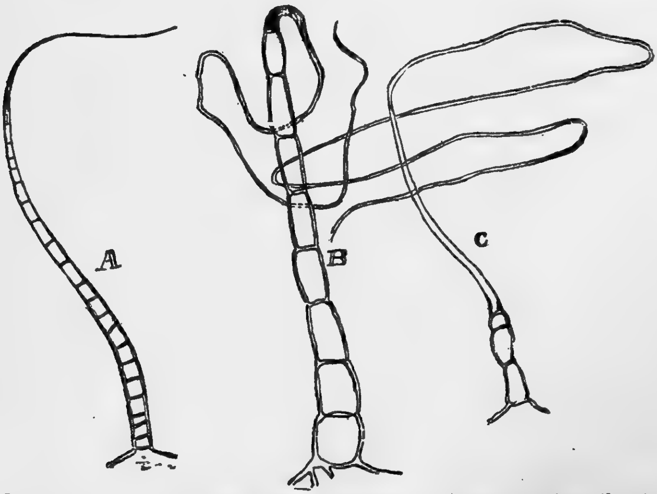


Fig. 88.—Hairs from Thistle (*Cnicus altissimus*). *A*, young hair from the stem before it has been drawn out; *B*, an older hair more highly magnified, after its extremity has been drawn out into a thread-like lash; *C*, hair with a long lash from the underside of a full-grown leaf. Highly magnified.—After Beal.

(*f*) Clustered or tufted hairs are found on many *Malvaceæ*, and the nearly related scales or peltate hairs on *Shepherdia*.

(*g*) Root-hairs are best obtained for study by growing seeds of mustard, radish, wheat, etc., on damp cotton or blotting-paper, and then making careful longitudinal sections of the terminal portion of the root at the place where the hairs are just appearing (usually several millimetres above the tip of the root). By making preparations in this way all stages of the development of these hairs may be studied in the same specimen.

(*h*) Glandular hairs are found in many groups of plants; they may be studied in *Petunia*, *Verbena*, *Primula*, *Martynia*, and the tomato.

(*i*) Apparently related to glandular hairs are the curious hairs from

which, as pointed out by Professor Beal,* are drawn out the long thread-like lashes which are so abundant on the leaves of some thistles and other *Compositæ* (Fig. 88). These lashes appear to be of the nature of secretions, and they are capable of being drawn out to an astonishing length. These are, in turn, much like the glandular hairs on the leaves of *Dipsacus sylvestris*, discovered by Francis Darwin,† and from which motile protoplasmic filaments protrude. Mr. Darwin concludes that they have the power of absorbing nitrogenous matter.

130.—Stomata (singular, *Stoma*). These structures consist, in most cases, of two specially modified chlorophyll-bearing cells, called the Guard-cells, which have between them a cleft or slit passing through the epidermis (Figs. 89, 90). These openings are always placed directly over interior intercellular spaces. Stomata are developed from, and in their distribution always have a relation to, the epidermal cells; in an epidermis composed of regular cells there is more or less regularity in the arrangement of the stomata; but when the epidermal cells are irregular the stomata are also irregularly placed.

They occur on aerial leaves and stems most abundantly, being sometimes exceedingly numerous, and are exceptionally found on other parts, as the sepals, petals, and carpels of the flowers. On submerged or underground stems and leaves they are found in less numbers, and from true roots they are always absent. The stomata on leaves are generally confined to the lower surface, and when present on the upper they are usually much fewer in number; there are, however, some exceptions to this.

131.—Their development generally takes place in the following way: in a young epidermis-cell a partition forms at right angles to the plane of the epidermis, cutting off a portion of the cell; this in one series of cases becomes the mother-cell of the stoma; in another series of cases, however, it is divided one or more times by subsequent partitions before the mother-cell is formed. In either case, when once

---

*** In an article entitled "How Thistles Spin," in the *American Naturalist*, 1878, page 643. See also an article by the same writer on "Hairs and Glandular Hairs of Plants: their Forms and Uses," in the same volume of the journal named, on page 271.**

† See his account, with a plate, in *Qr. Jour. of Mic. Science*, 1877, p. 245.

the mother-cell is formed a median partition-wall forms in it, and gradually becomes separated into two plates, which eventually separate and form a pore through the epidermis. The two halves of the mother-cell become symmetrically rounded off into semilunar or semicircular forms, and constitute the guard-cells before mentioned. The details of the foregoing process in one of its more complex forms are illustrated in Fig. 91, *A* and *B*. The splitting of the middle partition-wall of the mother-cell is shown in the successive sections (Fig. 92).

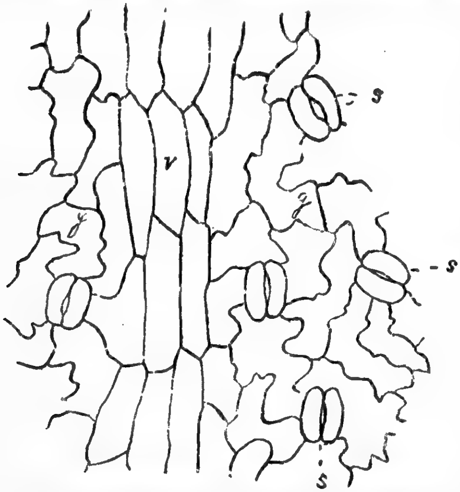


Fig. 89.—Stomata from the under surface of the leaf of *Echinocystis lobata*. *s*, *s*, stomata; *g*, *g*, irregular epidermis-cells between the veins of the leaf; *v*, elongated and regular epidermis-cells over a vein. × 250.—From a drawing by J. C. Arthur.

132.—In the light, under certain conditions of moisture and temperature, the guard-cells become curved away from each other in their central portions, thus opening the slit and allowing free communication between the external air and that in the intercellular spaces and passages of the leaf.

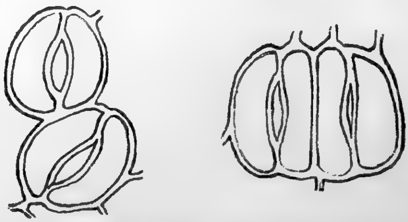


Fig. 90.—Double stomata from the under surface of the leaf of *Echinocystis lobata*. × 500.—From a drawing by J. C. Arthur.

(*a*) A superficial examination of stomata may be easily made by stripping off the epidermis, and mounting it in water or alcohol. Good sections of stomata are more difficult to make; they may be obtained,

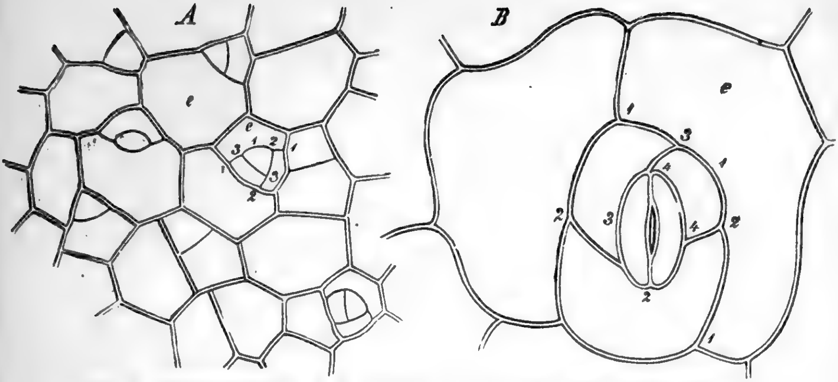


Fig. 91.—The development of the stomata of the leaf of *Sedum purpurascens.* *A*, a piece of very young epidermis, showing the early stages of the process. The numerals indicate the order of formation of the partitions; that marked 1, 1, 1, was formed first, then 2, 2, and last 3, 3; the cell enclosed by these three partitions is the stoma-mother-cell; *B*, a fully completed stoma; *e*, *e*, two original epidermis-cells—in the right hand one the new partition 1, 1, 1, first appeared; this was followed by 2, 2, 2, then by 3, 3, and 4, 4; lastly the cell thus formed became divided by a middle partition, which soon split, and thus formed the opening of the stoma.—After Sachs.

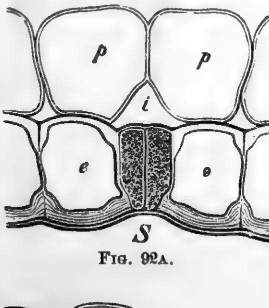


FIG. 92A.

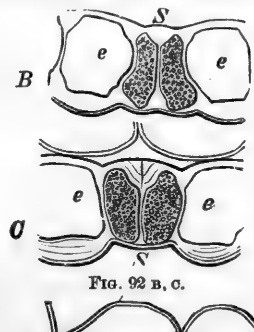


FIG. 92 B, C.

D

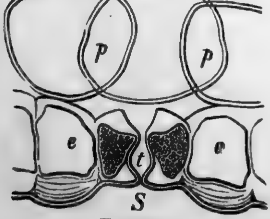
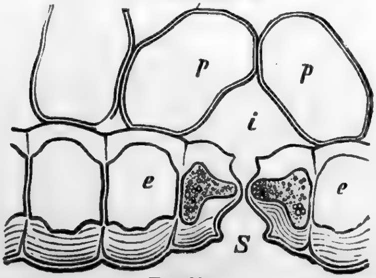


FIG. 92D.



E

FIG. 92E.

Fig. 92.—Development of the stomata of the leaf of *Hyacinthus orientalis*, seen in transverse section. *A*, the division of the mother-cell *S*; *e*, *e*, epidermis-cells; *p*, *p*, parenchyma-cells; *i*, small intercellular space; *B* and *C*, the same a little later; *D*, first separation of the two guard-cells by the splitting of the partition between them, forming the opening *t*; *E*, the fully formed stoma. × 800.—After Sachs.

however, by making a large number of very thin sections of the whole leaf (by placing it between two pieces of elder pith), when it will be found that in some cases stomata have been cut through in the manner shown in Fig. 92.

(*b*) Examples may be obtained from any of the higher plants, but those which are of a firm texture and have a smooth epidermis are best to begin with—*e.g.*, the hyacinth, tulip, the lilies, many grasses, fuchsia, lilac, etc.

(*c*) Weiss* determined the number of stomata on the epidermis of both surfaces of 167 leaves of plants ; some of his results are given below :

	In one square millimetre.		In one square inch.	
	Upper side.	Under side.	Upper side.	Under side.
Olea Europea	0	625	0	403,125
Vinca minor	0	477	0	308,665
Juglans nigra	0	461	0	298,345
Ailanthus glandulosa	0	386	0	248,970
Syringa vulgaris	0	330	0	212,850
Helianthus annuus	175	325	112,875	209,625
Brassica oleracea	138	302	88,910	194,790
Platanus occidentalis	0	278	0	179,310
Populus dilatata	55	270	35,475	174,150
Solanum dulcamara	60	263	38,700	169,635
Euphorbia cyparissias	0	259	0	167,055
Maclura aurantiaca	0	251	0	161,895
Betula alba	0	237	0	152,865
Berberis vulgaris	0	229	0	147,705
Pisum sativum	101	216	65,145	139,320
Buxus sempervirens	0	208	0	134,160
Prunus Mahaleb	0	204	0	131,580
Asclepias incarnata	67	191	43,215	123,195
Datura stramonium	114	189	73,530	121,905
Taxus baccata	0	166	0	107,070
Zea mais	94	158	60,630	101,910
Chenopodium ambrosioides	184	156	118,680	100,620
Ficus elastica	0	145	0	93,525
Ribes aureum	0	145	0	93,525
Populus monilifera	89	131	57,405	84,495
Pinus sylvestris	50	71	32,250	45,895
Anemone nemorosa	0	67	0	43,215
Lilium bulbiferum	0	62	0	39,990
Iris Germanica	65	58	41,925	38,410
Avena sativa	48	27	30,960	17,415

*In a paper on the Number and Size of Stomata, published in Pringsheim's "Jahrbücher für Wissenschaftliche Botanik," 1865.

(*d*) In the plants he examined he found that there were

54	species with from	1 to 100	stomata	per sq.	mm. =	645 to 64,500	per sq. inch		
38	"	"	100 to 200	"	"	" =	64,500 to 129,000	"	"
39	"	"	200 to 300	"	"	" =	129,000 to 193,500	"	"
12	"	"	300 to 400	"	"	" =	193,500 to 258,000	"	"
9	"	"	400 to 500	"	"	" =	258,000 to 322,500	"	"
1	"	"	500 to 600	"	"	" =	322,500 to 387,000	"	"
3	"	"	600 to 700	"	"	" =	387,000 to 451,500	"	"

(*e*) Morren's measurements* vary somewhat from those given by Weiss. The following, not given by Weiss, are taken from Morren's table:

	In one square millimetre.		In one square inch.	
	Upper side.	Under side.	Upper side.	Under side.
Trifolium pratense	207	335	133,515	216,075
Humulus Lupulus.........	0	256	0	165,120
Prunus domestica	0	253	0	163,185
Pirus Malus...............	0	246	0	158,670
Hedera helix..............	0	196	0	126,420
Vitis vinifera..............	0	155	0	99,975
Beta vulgaris.............	75	115	48,375	74,175
Pirus communis...........	0	91	0	58,695
Philadelphus coronarius....	0	86	0	55,470
Secale cereale.............	49	42	31,605	27,090

(*f*) The stomata of the so-called Compass Plant (*Silphium laciniatum*) are nearly equal in number on the two sides of the vertical leaves; there are on the true upper surface 82 per sq. mm. (= 52,700 per sq. inch), and on the under surface, 87 per sq. mm. (= 57,300 per sq. inch).†

(*g*) On most leaves the stomata are not distributed equally over all portions of either surface; they are not found on the veins, but are restricted to the areas between them. In some plants this restriction is accompanied by a further modification, as in *Ceanothus prostratus*, where the stomata are confined to the bottoms of sunken pits which occur on the under side of the leaves. In the long harsh leaves of *Stipa spartea* the stomata of the upper surface are restricted to the sides of the deep longitudinal channels which lie between the prominent nerves. (See Figs. 135–6, page 158.)

---

* Published first in *Bulletin de l'Academie royale de Belgique*, vol. 16, number 12, 1864, and also in part in Pringsheim's "Jahrbücher," etc., l. c.

† See an article in *American Naturalist*, 1877, p. 486: "Observations on *Silphium laciniatum*, the so-called Compass Plant," by C. E. Bessey.

(*h*) *Water-pores.* De Bary* describes under this name some curious stoma-like structures which occur on many plants. These, instead of containing air in their cavities, normally contain water. Their guard-cells, which are, in some cases at least, much like those of ordinary stomata, are immovable, and as a consequence the pore is incapable of enlargement or contraction. They are always found over the ends of small bundles of spiral vessels, which appear to pass into the pore cavities.

One form of these may be readily examined in the leaves of the fuch-

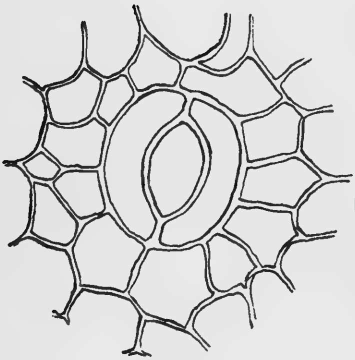


FIG. 93.

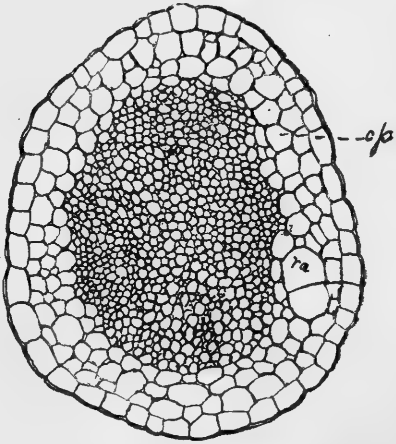


FIG. 94.

Fig. 93.—Surface view of the water-pore on the extremity of the leaf-tooth of *Fuchsia globosa.* × 500.—After Arthur.

Fig. 94.—Transverse section of leaf-tooth of *Fuchsia globosa; cp*, chlorophyll-bearing parenchyma, within which is the fibro-vascular bundle; *ra*, raphis-cells. × 125.—After Arthur.

sia, and the primrose (*Primula sinensis*). In the fuchsia they are found in the papillæ or small teeth on the margins of the leaves, and in the primrose, in the papillæ terminating the lobes and lobules. In *Fuchsia globosa* each leaf-tooth is provided with a single terminal pore (in some of the dark colored varieties there are several), which resembles an ordinary stoma (Fig. 93). Beneath the pore is a cavity, commonly filled with water (Fig. 95, *b*), which, by evaporation, deposits calcium carbonate upon the walls of the lining cells, thereby discoloring them. A fibro-vascular bundle is continued from the veins of the leaf through

* In "Vergleichende Anatomie der Vegetationsorgane," etc., 1877, on page 54, et seq. References are there given to the literature of the subject, which is both recent and limited. After Mettenius' paper in *Filices horti Lipsiensis*, others appeared by other writers in *Botanische Zeitung*, 1869, 1870, and 1871.

the tooth to the water-cavity; in the tooth it becomes greatly enlarged, and is there composed of spiral cells (tracheïdes), which surround a central mass of narrow elongated parenchymatous cells (Fig. 95, *c*, *g*). The bundle terminates by the free ends of the parenchyma-cells extend-

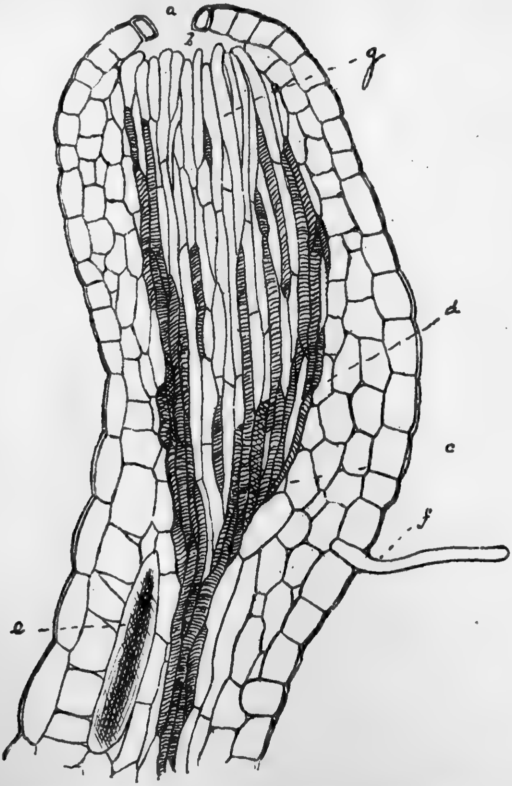


Fig. 95.—Vertical section of a leaf-tooth of *Fuchsia globosa*. *a*, vertical longitudinal section of water-pore; *b*, water-cavity; *c*, tracheïdes; *d*, chlorophyll-bearing parenchyma; *e*, large cell containing raphides; *f*, hair; *g*, parenchyma of the fibro-vascular bundle. The lower part of the figure passes into the leaf-blade. × 125.—After Arthur.

ing loosely into the water-cavity. Between the bundle and the epidermis of the leaf-tooth lie two or three cell layers of ordinary chlorophyll-bearing parenchyma, in which there are occasionally large cells containing raphides (Fig. 94, *cp* and *ra*).*

* The foregoing account of the water-pores of *Fuchsia globosa*, and the drawings for Figs. 93–4–5, are taken from an unpublished paper on "The Water-Pores of *Fuchsia globosa*," by J. C. Arthur.

Water-pores nearly like those of the fuchsia occur on some species of *Saxifraga, Heuchera, Mitella, Aconitum, Delphinium, Sambucus*, and many other plants.

Another form, more closely resembling the ordinary stomata (but of much larger size), occurs on *Tropæolum Lobbianum, Rochea coccinea*, and others.

§ III. The Fibro-vascular System.

133.—In most of the higher plants portions of the primary meristem early become greatly differentiated into firm elongated bundles, which traverse the other tissues. They are composed for the most part of tracheary, sieve, and fibrous tissues, together with a varying amount of parenchyma. These elementary tissues have, with some considerable variations in the different groups of plants, a general similarity of arrangement and aggregation throughout the Pteridophytes and Phanerogams. In a comparatively small number of cases laticiferous tissue is associated with the above-mentioned tissues. To these aggregations of tissues the name of Fibro-vascular Bundles has been given.*

134.—In many plants the fibro-vascular bundles admit of easy separation from the surrounding tissues; thus in the Plantain (*Plantago major*) they may readily be pulled out upon breaking the petioles. In the leaves of plants, where they constitute the framework, they are, by maceration, readily separated from the other tissues as a delicate network. In the stems of Indian corn the bundles run through the internodes as separate threads of a considerable thickness.

135.—It is impossible to fix upon a particular form as the type of the fibro-vascular bundle. It should be understood at the outset that the similarity between the bundles of widely separated groups of plants is only a general one, and that there are great differences in the details of their structure. It must further be borne in mind that these bundles are not themselves tissues, but aggregations of dissimilar tis-

* They are also called Vascular Bundles; this term ought, however, to be retained for those reduced bundles in which only vessels are present—*e.g.*, in the veinlets of leaves.

sues, any of which may be wanting in, or separated a little space from, the bundle. In short, the elementary tissues, particularly tracheary, sieve, fibrous, and parenchymatous tissues, are to be considered as the units, and the term Fibro-vascular Bundle as little more than a convenient expression of the usual condition of aggregation of these units.*

The general structure of fibro-vascular bundles will be more readily understood after the examination of a number of examples. Those which follow are not in any sense typical; they are only illustrative.

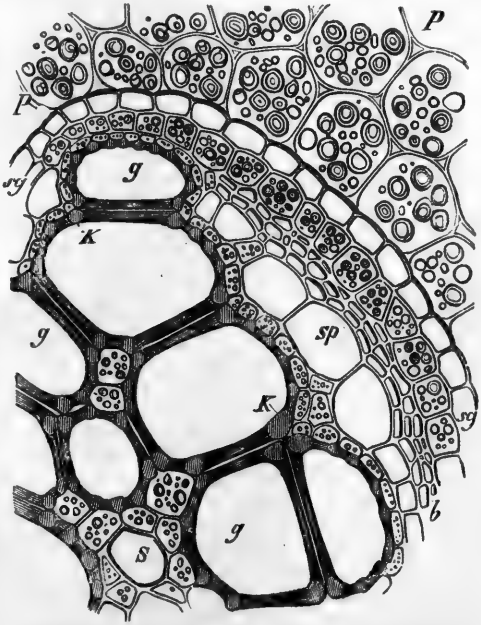


Fig. 96.—Part of a transverse section of the fibro-vascular bundle of the stem of *Pteris aquilina*; *s*, spiral vessel; *g*, *g*, scalariform vessels; *sp*, sieve tissue; *b*, fibrous tissue (protophloëm of Russow); *sg*, bundle sheath; *p*, starch-bearing parenchyma: *K*, *K*, thickened angles of scalariform vessels.—After Sachs.

136.—The fibro-vascular bundle of the stem of *Pteris aquilina* is composed of tracheary and sieve tissues, parenchyma, and a small amount of poorly developed fibrous tissue. In transverse section the bundle has usually an elliptical outline. The great mass of the bundle is made up of large scalariform vessels, which occupy its interior (*g*, *g*, *g*, Fig. 96). Enclosed in the scalariform tissue are masses of parenchyma and a few

* By considering the Fibro-vascular Bundle to be one of the structural units of the higher plants a serious mistake has been made, leading to profitless discussions and speculations as to its typical structure, and diverting attention from the study of its actual structure.

spiral vessels, the latter occurring near the foci of the elliptical cross-section of the bundle (*s*, Fig. 96). Surrounding, or partly surrounding, the tracheary portion of the bundle is a layer of sieve tubes (*sp*, Fig. 96), separated from the large scalariform vessels by a layer of parenchyma. Outside of the sieve tissue is a mass of fibrous tissue (*b*, Fig. 96), which is itself bounded externally by another layer of parenchyma. The whole bundle is surrounded by a layer of paren-

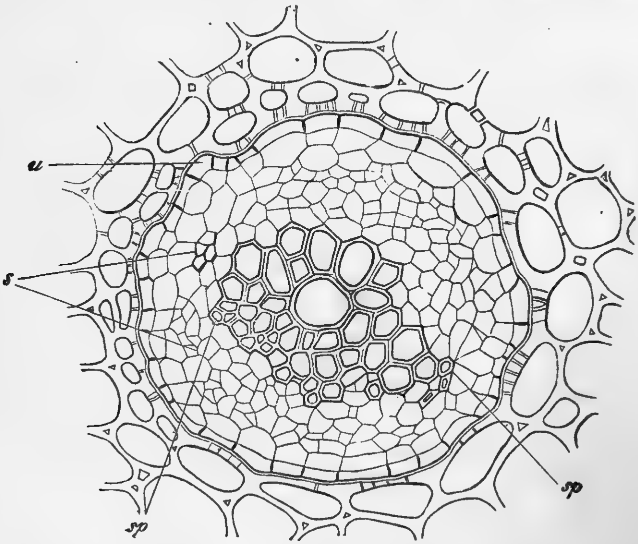


Fig. 97.—Transverse section of the fibro-vascular bundle of the rhizome of *Polypodium vulgare*; *sp*, *sp*, narrow spiral vessels in the edge of the mass of scalariform vessels; *s*, region of the sieve tissue filled with parenchyma and poorly developed sieve tissue; *u*, bundle sheath, outside of which is parenchyma. × 225.—After De Bary.

chyma differing from the other parenchymatous tissues in not containing starch in its cells; to this the name of Bundle Sheath has been given.

A noticeable feature in the structure of this fibro-vascular bundle is that the tissues have a concentric arrangement; the tracheary tissue is encircled by a layer of parenchyma;

See, in this connection, an article on "Some recent views as to the composition of the Fibro-vascular Bundles of Plants," by S. H. Vines, in *Qr. Jour. Mic. Science*, 1876, p. 388.

this by one of sieve tissue ; this again by fibrous tissue, and so on.

137.—A similar but not identical structure is found in the

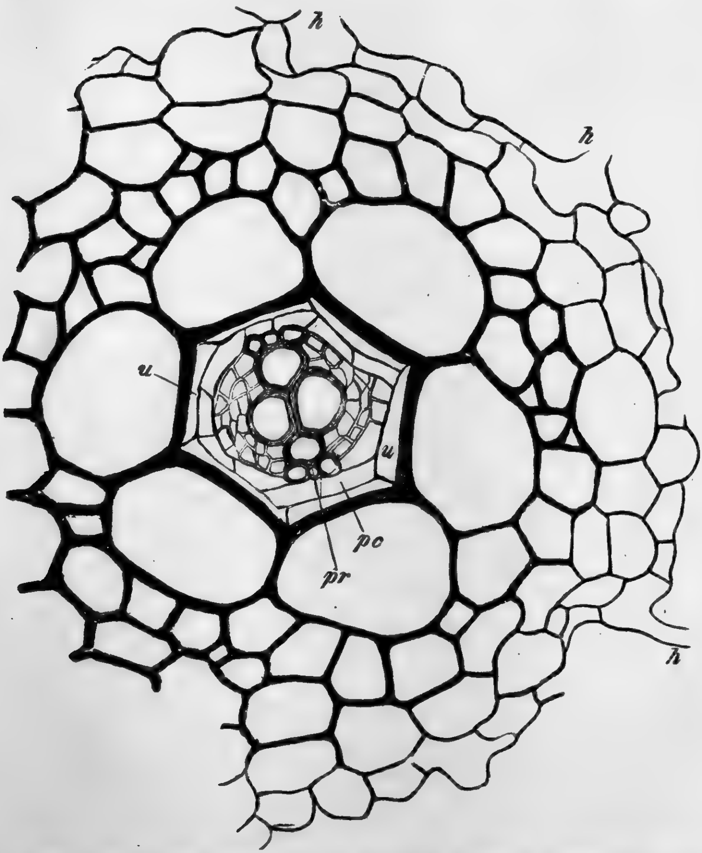


Fig. 98.—Part of the cross-section of an old root of *Adiantum Moritzianum*. *h*, *h*, hairs of the root surface ; *u*, *u*, bundle sheath (endodermis) ; between *h* and *u*, parenchyma ; *pc*, pericambium ; *pr*, a plate of tracheary tissue, which is bounded on each side by sieve tissue. × 225.—After De Bary.

bundle of the rhizome of *Polypodium vulgare*. Here the central portion of the stem is made up of scalariform tissue (Fig. 97, the larger, thicker-walled tissue), and this is surrounded by a tissue which may be regarded as but partly

differentiated, being composed of parenchyma and poorly developed sieve tubes (*s*, Fig. 97). The whole bundle is surrounded, as in *Pteris aquilina,* by a bundle sheath (*u*, Fig. 97). In the outer part of the mass of scalariform tissue are a few narrow spiral vessels (*sp, sp,* Fig. 97), but they are not sufficiently numerous to constitute a ring or layer.

138.—In the root of *Adiantum Moritzianum* the bundle consists of a central plate of tracheary tissue (*pr*, Fig. 98), with a mass of sieve tissue on each side of, but not quite enveloping it. Next outside of this is a layer of active parenchyma, the pericambium (*pc*, Fig. 98), and surrounding the whole is a poorly developed bundle sheath (*u*, Fig. 98).

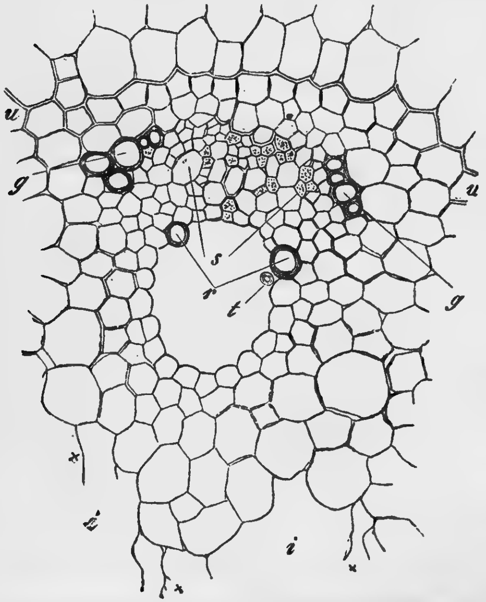


Fig. 99.—Transverse section of a fibro-vascular bundle of *Equisetum palustre*. *r*, *t*, ringed vessels on the border of a large intercellular canal; *s*, sieve tissue; *g*, *g*, groups of annular and reticulated vessels; *u*, the so-called general bundle sheath, which surrounds all the bundles; *i*, *i*, axial air canals; ×, ×, fragments of the ruptured cells. × 145. —After De Bary.

139.—In the stem of *Equisetum palustre* it is not so easy as in the foregoing cases to mark the limits of the bundles, which are arranged in a circle about the axis.* On the axial side of each bundle there are at first a few spiral and annular vessels, most of which, along with a considerable amount of parenchyma, are

*** In *Equisetum limosum*, however, there is a bundle sheath about each bundle, consequently there is in that species no difficulty as to the limits of the bundle.**

destroyed shortly after their formation, thus forming a wide canal (Fig. 99; *t*, spiral, and *r*, annular vessels on the border of the canal). Immediately in front of or outside of the canal is a considerable mass of sieve tissue, made up of true sieve tubes and the nearly allied cambiform or latticed cells (*s*, Fig. 99). Right and left of the sieve tissue lie a few annular and reticulated vessels (*g*, *g*, Fig. 99). Exterior to all the bundles (in this species) is a cellular layer, which has received the name of bundle sheath, but which, probably, has no relation to the layer so named that surrounds each fibro-vascular bundle of some plants.

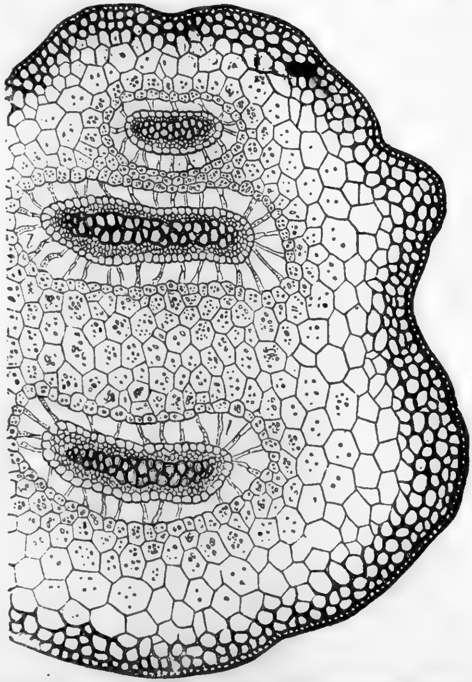


Fig. 100.—Cross-section of the stem of *Selaginella inæquifolia*, showing three bundles; in each bundle the inner thicker walled tissue is composed of scalariform vessels, with a few narrow spiral vessels on each extreme margin; surrounding the scalariform tissue is the thinner walled sieve tissue, and around this again is a layer of cells, which may be called the bundle sheath; *l*, *l*, intercellular spaces surrounding the bundles. × 150.—After Sachs.

140.—The structure of the bundle in *Selaginella inæquifolia* bears a considerable resemblance to that of *Pteris aquilina*. There is in each bundle a central plate of tracheary tissue, consisting of a few narrow spiral vessels in its two edges and a remaining mass of scalariform vessels (Fig. 100). The tracheary portion is surrounded by a tissue of elongated, thin-walled tissue which is, at least in part, a sieve tissue. In this and allied species

the bundles are curiously isolated from the surrounding ground tissues of the stem.

141.—The bundle of the nearly related *Lycopodium complanatum* is much more complex in its structure (Fig. 101). Here there are four parallel plates of tracheary tissue, each having a structure like the single plate of the bundle of *Selaginella inæquifolia.* Between the tracheary plates there is in each case a row of sieve tubes imbedded in a lignified tissue composed of elongated cells (sclerenchyma, or fibrous

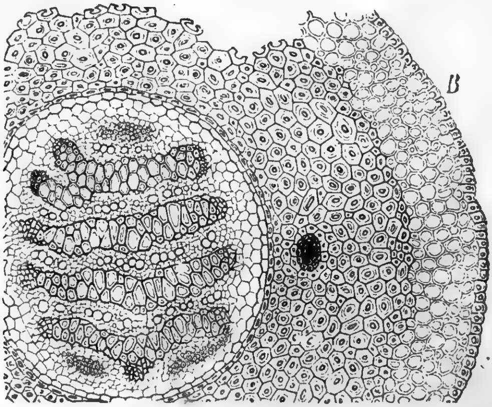


Fig. 101.—Cross-section of the stem of *Lycopodium complanatum.* The fibro-vascular bundle is composed of four plates of tracheary tissue (darker in the figure), between which are masses of lignified tissue composed of elongated cells; each of these latter masses encloses a row of sieve tubes (larger and thicker walled in the figure); the bundle sheath is seen to bound on its inner side a thick mass of very thick walled fibrous tissue; exterior to this (toward *B*) is a layer of chlorophyll-bearing parenchyma, bounded by a well-developed epidermis. The small vessels at the extreme edges of the plates of tracheary tissue are narrow and spirally marked; the remainder of each plate is composed of scalariform vessels. × 100.—After Sachs.

tissue?). Around this central fibro-vascular portion there is a layer of parenchyma, and outside of this a bundle sheath, which is commonly regarded as marking the boundary of the bundle; it is doubtful, however, whether it should be so considered, as exterior to it lies a thick mass of fibrous tissue which completely envelops all the previously described tissues.*

---

* Sachs ("Text-Book," p. 418) regards the stem of Lycopodium as composed of four united bundles and compares them to the separate bundles of Selaginella. De Bary ("Anatomie," etc., p. 362), on the

142.—In the fibro-vascular bundle of the stem of Indian corn (*Zea mais*) the central portion is composed of tracheary

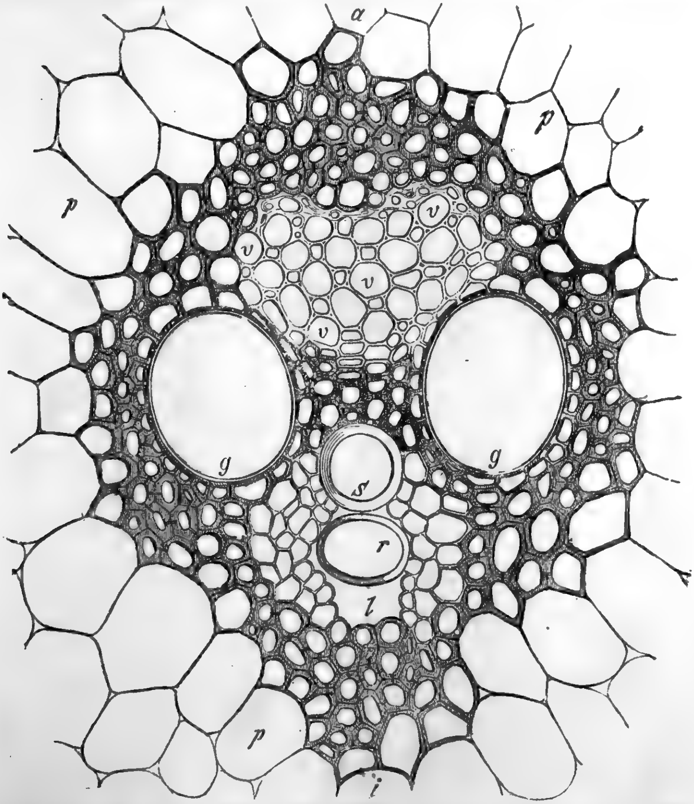


Fig. 102.—Transverse section of fibro-vascular bundle of Indian corn (*Zea mais*). *a*, side of bundle looking toward the circumference of the stem; *i*, side of bundle looking toward the centre of the stem; *p*, thin-walled parenchyma of the fundamental tissues of the stem; *g*, *g*, large pitted vessels; *s*, spiral vessel; *r*, ring of an annular vessel; *l*, air-cavity formed by the breaking apart of the surrounding cells; *v*, *v*, latticed cells, or soft bast, a form of sieve tissue. × 550.—After Sachs.

tissue, consisting of pitted, spiral, ringed, and reticulated vessels (Fig. 102, *g*, *g*, *s*, *r*, and the tissue between *v*—*s*, *g*—*g*)

---

other hand, considers the cylindrical portion in the centre as but one bundle, belonging to what he terms the Radial type. Both agree in considering the fibrous tissue outside of the bundle sheath as not belonging to the bundles; but certainly if this is *one bundle*, there is as good reason for including the fibrous cylinder in it as there is in the case of the bundle of Indian corn.

Lying by the side of the tracheary tissue (on its outer side as it is placed in the stem) is a mass of sieve tissue, composed of latticed cells (*v*, *v*, Fig. 102). Surrounding the whole is a thick mass of fibrous tissue composed of elongated, thick-walled cells (the shaded ones in the figure).

143.—The fibro-vascular bundle of the flowering-stalk of *Acorus calamus* bears a close resemblance to that of Indian corn. Like that, it has a central tracheary portion (*g*, Fig. 103), which has lying exterior to it a mass of sieve tissue (*w*, Fig. 103). On the inner side there is a large intercellular canal, evidently holding the same relation to the other tissues that the smaller canal does in the bundle of Indian corn. The exterior of the bundle is here also made up of a thick mass of fibrous tissue.

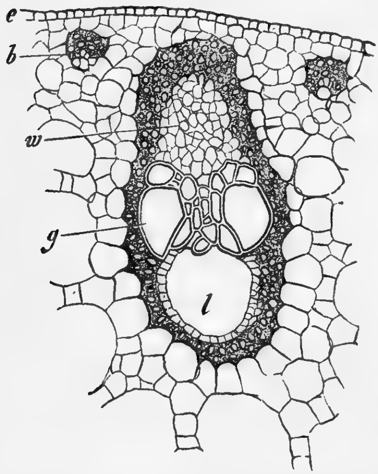


Fig. 103.—Transverse section of a portion of the general peduncle of *Acorus calamus*. *e*, epidermis; *b*, small fibro-vascular bundle; in the large bundle *w* is the sieve tissue, *g* the tracheary tissue, *l* an intercellular canal; the periphery of the bundle is composed of thick-walled fibrous tissue (figured dark). × 145.—After De Bary.

144. — In the fibro-vascular bundle of the adventitious roots of *Acorus calamus* the arrangement of the tissues is very different from that described above. Here there are many radially placed plates of tracheary tissue (*pp*, Fig. 104), which alternate with thick masses of sieve tissue (*ph*, Fig. 104). Between these alternating tissues, and within the circle formed by them, there is a mass of parenchymatous tissue. The whole bundle is separated from the large-celled parenchyma of the root by a well-marked bundle sheath (*s*, Fig. 104); the latter is bounded interiorly by a layer of active thin-walled cells — the pericambium — from which new roots originate. In the older root, the central cell mass (which,

as described above, is in younger specimens composed of parenchyma) is transformed into sclerenchyma (Fig. 105).

145.—The fibro-vascular bundles of *Ricinus communis* have an arrangement in the stem, and a general structure somewhat similar to those of *Equisetum palustre,* described above. The limits of the bundles are so poorly marked that

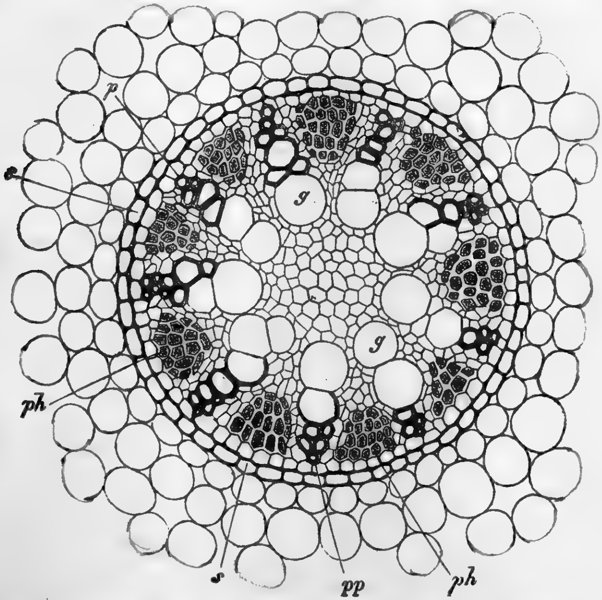


Fig. 104.—Transverse section of the fibro-vascular bundle of the root of *Acorus calamus.* *s*, bundle-sheath (also called endodermis), with parenchyma outside and a single layer of pericambium-cells inside; *pp*, plates of radially-placed tracheary tissue; *ph*, bundles of sieve tissue; *pp*, narrow peripheral (and first formed) vessels; *g*, large and still young vessel.—After Sachs.

in places it is impossible to tell whether the tissues belong to them or to the surrounding ground tissues.

The inner portion of the bundle (*g, g, t, t*, Fig. 106, and *s* to *t*, Fig. 107) is made up of tracheary tissue of several varieties; on the inner edge of this tracheary portion lie several spiral vessels (*s, s*, Fig. 107); next to these, on their outer side, are scalariform and pitted vessels (*t, t, g, g*, Fig. 106, *l, t, t′*, Fig. 107), intermingled with elongated cells, whose walls are pitted

(h, h', h'', h''', Fig. 107). The last-named are clearly related to the vessels which surround them, and from which they differ only in their less diameter, and in having imperforate horizontal or oblique septa. They are doubtless properly classed with the Tracheïdes (see p. 84). On the outer side of the tracheary portion just described lies a mass of narrow, somewhat elongated, thin-walled cells, which constitute a true meristem tissue, to which the name of Cambium* has been given (*c*, *c*, Figs. 106 and 107). Next to the cambium

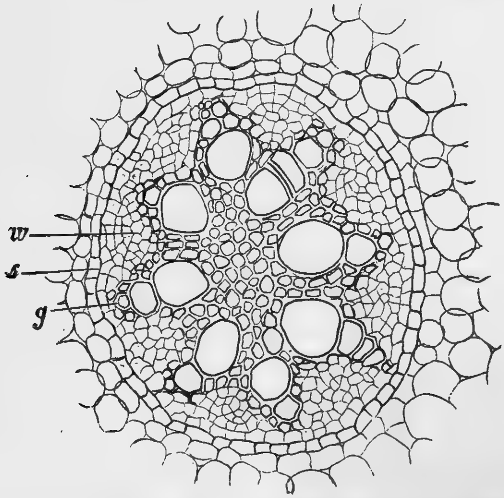


Fig. 105.—A very thin cross-section of the radial fibro-vascular bundle of an old adventitious root of *Acorus calamus*. *g*, the radial plates of tracheary tissue; *w*, the sieve tissue alternating with the plates of tracheary tissue; *s*, the bundle-sheath; the tissue in the centre of the bundle is sclerenchyma. × 145.—After De Bary.

lie, in order, sieve tissue and parenchyma; these do not occupy separate zones, but are more or less intermingled, forming a mass sometimes called the Soft Bast (*y*, *y*, *y*, Fig. 106, and *p*, Fig. 107). The sieve tissue includes sieve tubes and cambiform or latticed cells. In the extreme outer border of the bundle is a mass of fibrous tissue (*b*, *b*, Figs. 106 and 107). The layer of starch-bearing cells just outside of the last-named tissue is the so-called bundle sheath.

---

* Cambium, a low Latin word, meaning a liquid which becomes glutinous. The term was introduced when the real structure of the part to which it was applied was not understood.

146.—The bundle of the adventitious root of *Ranunculus repens* is very different from the one just described. It may be briefly described as composed of a mass of tracheary tis-

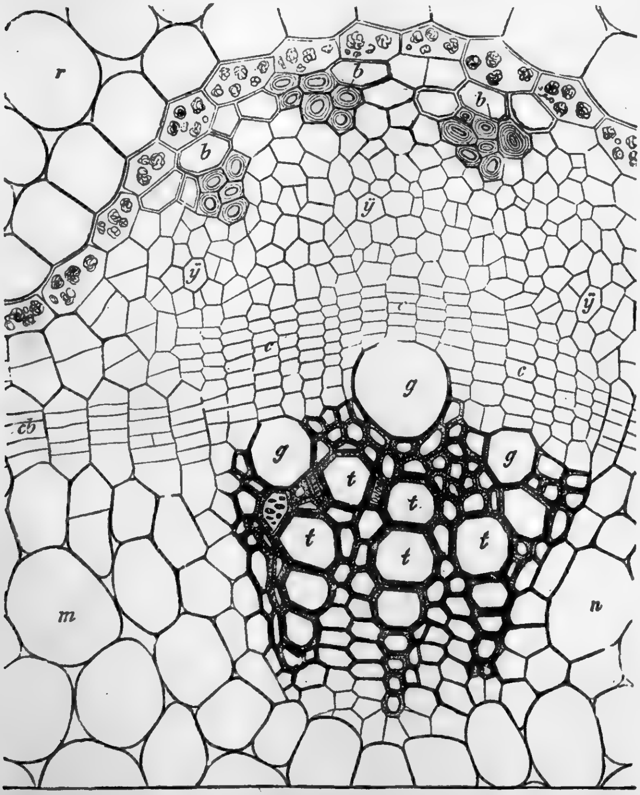


Fig. 106.—Transverse section of hypocotyledonary portion of stem of *Ricinus communis*. *r*, *r*, parenchyma of the primary cortex ; *m*, parenchyma of the pith ; *b*, bast fibres ; *y*, *y*, soft bast ; *c*, cambium ; *g*, *g*, large pitted vessels ; *t*, *t*, smaller pitted vessels ; *cb*, continuation of the cambium into the parenchyma lying between the bundles—the parenchyma-cells are repeatedly divided by tangential walls. Between the primary cortex *r* and the fibrous tissue of the phloëm lies a layer, the so-called bundle-sheath, filled with compound starch grains. Highly magnified.—After Sachs.

sue, which is cross-shaped, as seen in transverse section (*g*, *r*, *g*, Fig. 108), and four masses of sieve tissue, which lie in the angles between the projecting portions of the tracheary tissue. Around the whole is a layer of pericambium (*p*,

Fig. 108), and exterior to this is the bundle sheath (u, Fig. 108).

147.—In Gymnosperms and Dicotyledons the fibro-vascular bundles of the stems have a structure essentially like that of *Ricinus communis,* described above. In them it is evident at a glance that the bundle is divided into two somewhat similar portions, an inner and an outer, by the cam-

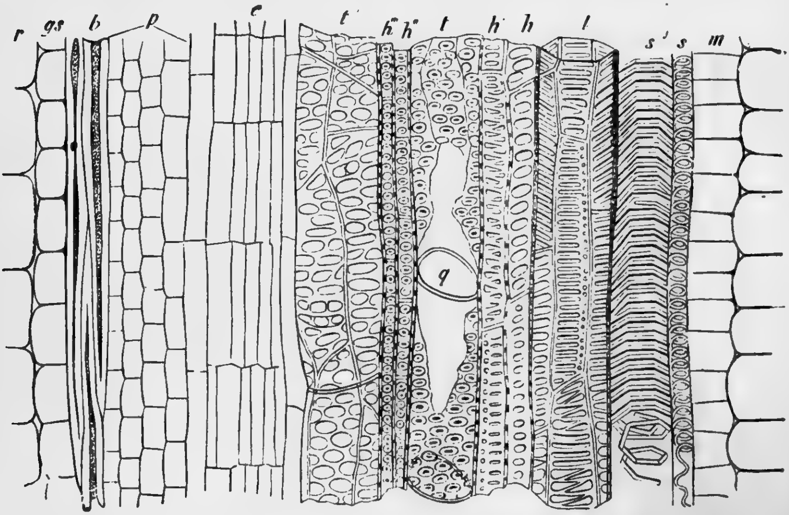


Fig. 107.—Longitudinal radial section of the fibro-vascular bundle of the hypocotyledonary stem of *Ricinus communis* (the transverse section being shown in Fig. 106). r, parenchyma of the primary cortex; gs, bundle sheath; m, parenchyma of the pith; b, bast fibres; p, phloëm parenchyma; c, cambium; the row of cells between c and p is afterward developed into a sieve-tube—this and c constitute the soft bast; s, the first-formed narrow spiral vessel; from s the development of the xylem portion of the bundle is toward t; s', wide spiral vessel; l, scalariform vessel; t, t', wide pitted vessels; q, the absorbed septum; h'', h''', tracheïdes (?); h, h', forms of cells apparently intermediate between pitted vessels and tracheïdes. Highly magnified.—After Sachs.

bium zone. Nägeli,* who first pointed out these divisions, named the inner one the Xylem portion, because from it the wood of the stem is formed; the outer he named the Phloëm portion, for the reason that it develops into bark.† In some cases the similarity between the structure of xylem

* "Beiträge zur Wissenschaftlichen Botanik," 1858.

† Xylem from ξύλον, wood; Phloëm from Greek φλοιός, bark.

and phloëm is so marked that they are said to be composed of corresponding tissues, (1) Vascular, (2) Fibrous, and (3) Parenchymatous.* The vascular tissues are, on the one hand, the tracheary tissue found only in the xylem, and on the other, the sieve tissue of the phloëm. The fibrous tissue of the xylem is the variety with the shorter and harder

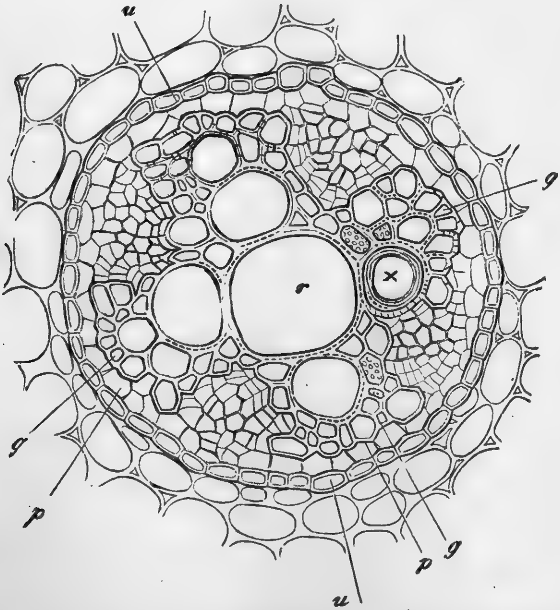


Fig. 108.—Cross-section of the fibro-vascular bundle of an old adventitious root of *Ranunculus repens*. *g*, *g*, *g*, the outer margins of the radial plates of tracheary tissue; *r*, a large central pitted vessel; ×, septum in pitted vessel, with its central portion absorbed; *p*, pericambium; *u*, bundle sheath; between the four projecting parts of the tracheary portion of the bundle, and just within the pericambium, lies the sieve tissue. × 145.—After De Bary.

fibres, known as wood fibres; that of the phloëm is composed of the longer and tougher bast fibres. The parenchyma of the two portions is much alike.

* Attention should be called here to the fact that in a good many orders of Phanerogams the laticiferous vessels are constituent parts of the fibro-vascular bundles. Thus in Cichoriaceæ, Campanulaceæ, Papaveraceæ, Asclepiadaceæ, Apocynaceæ, and Acerineæ they occur in the phloëm; in Papayaceæ and Aroideæ they occur in the xylem.

148.—Nägeli extended this classification of the tissues to the fibro-vascular bundles of Monocotyledons, and subsequently it has been still further extended so as to include all kinds of fibro-vascular bundles. In every case the tracheary portion is the essential, or most constant, characteristic of the xylem, as the sieve tissue is of the phloëm.

These terms are valuable when used in reference to the fibro-vascular bundles of the stems of Phanerogams; they may also be valuable, if properly used and understood, when applied to other forms of the fibro-vascular bundle. The xylem portions of the stem bundles of different plants among the Phanerogams are homologous parts of the tissue systems—the bundles; but when the term xylem is applied to certain parts of two dissimilar bundles—*e.g.*, of *Ricinus* (Fig. 106) and *Lycopodium* (Fig. 101)—no homology of parts should be understood. The tissues themselves, in some cases of dissimilar bundles, may be homologous, but they are *homologous tissues*, and not *homologous parts of a system* of tissues.* When, therefore, these terms are used in the present work, it must be borne in mind that they do not necessarily convey the idea of homology of parts.

149.—De Bary's † recent structural classification of fibro-vascular bundles is useful in designating their general plan. He includes all forms under three kinds, viz., (1) the Collateral bundle, which has one mass of xylem by the side of a single mass of phloëm; this is the form of all bundles of the stems of *Equisetum*, and of the stems and leaves of Phanerogams ‡ (Figs. 99, 102, 103, 106, 107); (2) the Concentric

---

* This point, which is an important one, may be made clearer by an illustration from zoology. The nervous *tissue* of one animal is the homologue of that found in any other, but the nervous *system* of one may or may not be the homologue of the other. The nervous system of the bee, for example, is not the homologue, but the analogue, of that of the ox; it is, however, the homologue of the nervous system of the lobster. The brain of the ox and the brain of the bee are not homologues *as parts of a system,* but they are homologues as *tissues.*

† "Vergleichende Anatomie," etc., p. 331, et seq.

‡ In the Cucurbitaceæ and some other orders there is a mass of sieve tissue on the inner side of the xylem, so that the latter is between two

bundle, which has its tissues arranged concentrically around one another; this is the bundle of the stems and leaves of ferns (with a few exceptions), Selaginellæ, and a few exceptional cases in Phanerogams (Figs. 96, 97, 98, 100); (3) the Radial bundle, which has its tissues arranged radially about its axis; such a bundle occurs in the stems of *Lycopodium*, and it is the primary bundle of the roots of most Pteridophytes and Phanerogams (Figs. 101, 104, 105, 108).

150.—The development of the fibro-vascular bundle takes place in this wise: in the previously uniform Primary Meristem there arises an elongated mass of cells, constituting the Procambium of the bundle; as it grows older the cells, which were at first alike, become changed into the vessels, fibres, and other elements of the bundle tissues. In the fibro-vascular bundle of the stems and leaves of Gymnosperms and Dicotyledons this change begins on the two sides of the bundle—*i.e.*, on the outer edge of the phloëm and the inner edge of the xylem; from these points the change into permanent tissue advances from both sides toward the centre of the bundle. In some cases (*e.g.*, in the leaves) all of the procambium is changed into permanent tissue, forming what is termed the *closed* bundle; in other cases there is left between the phloëm and xylem a narrow zone of the procambium (now called the Cambium), forming what is known as the *open* bundle.

151.—In the stem and leaf bundles of Monocotyledons the development of procambium into permanent tissue is essentially as in Dicotyledons and Gymnosperms, with this difference, that here they all become closed. In Pteridophytes and the roots of Phanerogams the development, while agreeing in general with the foregoing, is quite different as to details; all are closed, unless those in the roots of Dicotyledons and Gymnosperms should be shown to be exceptions.

152.—The fibro-vascular bundles of leaves and the reproductive organs are quite generally reduced by the absence

---

so-called phloëm portions. Such bundles are considered by De Bary to be variations of the collateral form, and he designates them as bi-collateral bundles.

of one or more tissues; this reduction may be so great as to leave but a single tissue, which in many cases is composed of only a few spiral vessels or tracheïdes (Fig. 109). In other cases, instead of spiral vessels the bundle may consist of a few fibres of bast; or of elongated, thin-walled cells, which are doubtless to be regarded as meristem-cells which failed to fully change into one of the ordinary permanent tissues; this last is a very common accompaniment of reduced bundles.

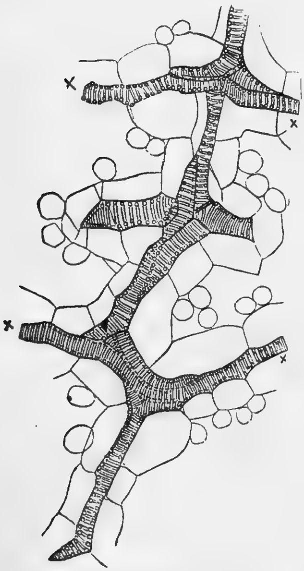


Fig. 109.—Terminal ramifications of the reduced fibro-vascular bundles of the leaf of *Psoralea bituminosa;* the ends ×, ×, are cut off in making the preparation, the others are the actual termini; the bundles are seen to be composed of spiral tracheïdes, and spiral vessels resulting from their fusion; around the bundles are seen the cells of the chlorophyll-bearing parenchyma. × 225.—After De Bary.

(*a*) In the study of the structure of fibro-vascular bundles much care is required in the preparation of the specimens. The thin transverse sections are obtained by ordinary processes with no great difficulty, but such is not the case with the longitudinal sections; they must not only be extremely thin, but must run parallel with the cells and fibres, and moreover, must be sufficiently large to show all, or a considerable part, of the bundle. It is necessary also to have several longitudinal sections, and to know the exact position of each one when compared with the transverse section.

(*b*) The most satisfactory results can be obtained only by the use of some mechanical section-cutter.* In most cases the sections are made more easily after soaking the stems, roots or leaves used in alcohol.

(*c*) In many cases it is profitable to macerate some of the longitudinal sections in nitric acid and potassium chlorate (Schulze's maceration), so as to permit of an isolation of the fibres, cells, and vessels.

(*d*) Good specimens for study may be obtained from any of the higher plants, but the examination will be most profitable if the order

* For the various contrivances used for cutting sections see the common books on microscopy, also *American Naturalist,* 1874, p. 59; *American Quarterly Microscopical Journal,* 1879, p. 131, and several articles in *Qr. Jour. Mic. Science,* 1870, 1874, 1875, 1877.

in the following list of examples is observed: (1) the rhizomes and roots of ferns; (2) stems of *Selaginella* and *Lycopodium;* (3) stems of Monocotyledons; (4) stems of *Equisetum;* (5) young stems of Gymnosperms and Dicotyledons; (6) roots of Phanerogams; (7) reduced bundles of leaves.

(*e*) The discussion of the disposition of the bundles in the stem, and their relation to the leaf bundles, together with the development and structure of secondary bundles, belongs properly to the special anatomy of the Phanerogams. (See Chapter XX.)

§ IV. The Fundamental System, or the System of Ground Tissues.

153.—These terms refer to the mass of various tissues lying within the epidermis, and not included in the fibro-vascular bundles, when they are present. In passing down through the lower plants this inner mass becomes more and more simple, until it is composed of but one homogeneous tissue, when the term *system* can no longer be profitably applied to it; in passing to the higher plants, on the other hand, there is in this portion of their structure an increasing complexity, which comes at last to more than equal that of either the epidermal or fibro-vascular systems.

154.—In its fullest development, the fundamental system may contain parenchyma of various forms, collenchyma, sclerenchyma, laticiferous tissue, and possibly also fibrous tissue.* Their arrangement, within certain limits, presents a considerable degree of similarity in nearly related groups of plants, but this is by no means as marked as in the case of the fibro-vascular system.

---

* It is a question whether fibrous tissue occurs in the fundamental system; there are some cases (*e.g.*, in Ferns, Lycopodiaceæ, etc.) which appear to show that it does, but possibly they admit of other interpretation. It should be mentioned here that many eminent botanists (notably Schwendener, Russow, Falconberg, and De Bary) hold that *all* fibrous tissue belongs to the fundamental system, and as a consequence, that it in no case is a proper constituent of the fibro-vascular bundle. This is, however, nothing more than making a typical form of bundle (composed of tracheary and sieve tissues), and then insisting that all tissues not found in the type are extra-fascicular, a course which cannot be followed in this book.

(1.) Parenchyma is the most constant of the fundamental tissues; it makes up the whole of the interior plant-body in those cases where there has been no differentiation into more than one tissue, and from here, it is present in varying amount in nearly all (if not all) cases up to and including the highest plants. In stems of Monocotyledons it makes up the mass of tissue lying between the scattered bundles, and in stems of Gymnosperms and Dicotyledons it constitutes the pith and portions of the bark.

(2.) Collenchyma, when present, as it frequently is in the stems and leaves of Dicotyledons, is always either in contact with or near to the epidermis.

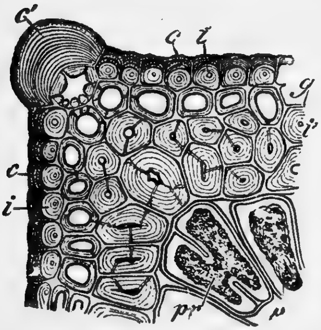


Fig. 110.—Margin of leaf of *Pinus pinaster*, transverse section; *c*, cuticularized layer of outer wall of epidermis; *i*, inner non-cuticularized layer; *c'*, thickened outer wall of marginal cell; *g*, *i'*, hypoderma of elongated sclerenchyma; *p*, chlorophyll-bearing parenchyma; *pr*, contracted protoplasmic contents. × 800.—After Sachs.

(3.) Sclerenchyma is common beneath the epidermis of the stems and leaves of Bryophytes, Pteridophytes, and Phanerogams. It appears to replace collenchyma in parts having greater firmness than that given by the latter. Some forms of sclerenchyma are scarcely to be distinguished from fibrous tissue—*e.g.*, in the hypoderma of pine leaves (Fig. 110, *g*, *i'*). It may be that the supposed cases of fibrous tissue among the fundamental tissues will turn out to be sclerenchyma instead.

(4.) Laticiferous tissue may occur, apparently, in any portion of the fundamental system of Phanerogamous plants.

155.—It is thus seen that in general the tissues of the fundamental system are so disposed that the periphery is harder and firmer than the usually soft interior, although there are many exceptions. This general structure has given rise to the term Hypoderma for those portions of the fundamental system which lie immediately beneath, or near to the epidermis. Hypoderma is not a distinctly limited portion—in fact, it is often difficult to say how far it does extend;

however, it usually includes several, or even many, layers of cells, or the whole of each of the tissue-masses (*e.g.*, collenchyma, sclerenchyma, etc.) which immediately underlie the epidermis (Fig. 110, *g*, *i*).

The remaining portion of the fundamental system, inside of the hypoderma, is designated by Sachs as the Intermediate tissue. The term is of but little value in many of the higher plants, where more particular names may be applied; but in some Monocotyledons, most Pteridophytes, and in Bryophytes it is very serviceable.

156.—Cork. Within the zone which the hypoderma includes there frequently takes place a peculiar development of the young parenchyma, giving rise to layers of dead cells, whose cavities are filled with air only. The walls in some cases (*e.g.*, the cork-oak) are thin and weak, while in others (*e.g.*, the beech) they are much thickened, and in all cases they are nearly impermeable to water. True cork is destitute of intercellular spaces, its cells being of regular shape (generally cuboidal) and fitted closely to each other (Fig. 111).

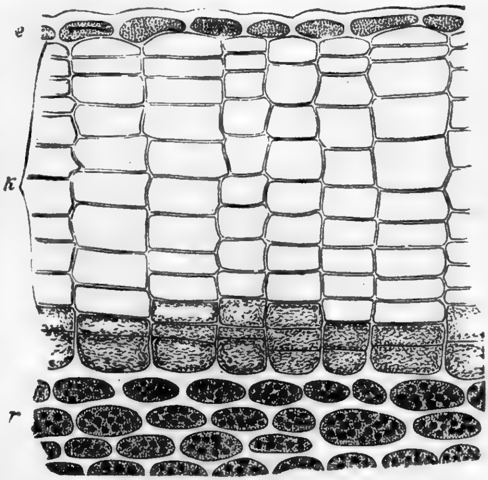


Fig. 111.—Transverse section of one-year old stem of *Ailanthus glandulosus*. *e*, epidermis; *k*, cork-cells; *r*, inner green cells, the phelloderma; between *k* and *r* a layer of cells filled with protoplasm, called the phellogen or cork cambium. × 350.—After Prantl.

157.—Cork substance is formed by the repeated subdivision of the cells of a meristem layer of the fundamental tissue (Fig. 111); these continue to grow and divide by partitions parallel to the epidermis, forming layers of cork with its cells disposed in radial rows (Fig. 111, *k*). Shortly after

their formation the cork-cells lose their protoplasmic contents, while beneath them new cells are constantly being cut off from the cells of the generating layer; in this way the mass of dead cork tissue is formed and pushed out from its living base.

158.—The generating tissue is called the Phellogen,* or Cork-cambium; it occurs not only in the hypoderma, but in any other part of the fundamental system, and, as will be shown hereafter, in the secondary fibro-vascular bundles. When a living portion of a plant is injured, as by cutting, the uninjured parenchyma-cells beneath the wound often change into a layer of phellogen, from which a protecting mass of cork is then developed.

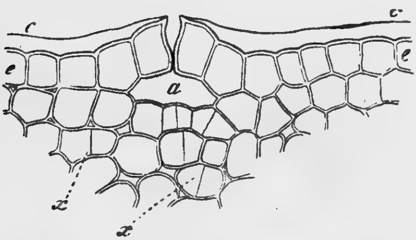


Fig. 112.—Transverse section of a portion of the internode of a young twig of *Betula alba*. *c*, cuticle, somewhat separated from the epidermis; *e*, *e*, epidermis; *a*, cavity under the stoma seen in cross-section above; *x*, *x*, cells which are beginning the process of multiplication by fission, constituting the phellogen of the future lenticel. × 375.—After De Bary.

159.—*Lenticels* are in many cases the result of a restricted corky growth just beneath a stoma. Phellogen consisting of a few cells of the hypoderma, is formed immediately below a stoma (Fig. 112, *x*); by the growth of cork from this phellogen the epidermis is pushed out and finally ruptured, exposing the roundish or elongated mass of cork† (Fig. 113). Lenticels are of frequent occurrence on the young branches of birch, beech, cherry, elder, lilac, etc., and may be distinguished by the naked eye as slightly elevated roughish spots, usually of a different color from the epidermis.

(*a*) The examination of the tissues of the fundamental system may in general be made with considerable ease, by making transverse, tangential and radial sections.

* From the Greek φελλος, cork.

† It appears quite certain that not all lenticels develop from the hypoderma beneath stomata; phellogen forms beneath the epidermis at other points, and gives rise to lenticels in a way essentially as in the other cases.

(*b*) Ordinary herbaceous Dicotyledons furnish the best examples of fully developed fundamental tissues; they can be most easily examined after soaking for some time in alcohol.

(*c*) Examples of thin-walled cork are, of course, best obtained from

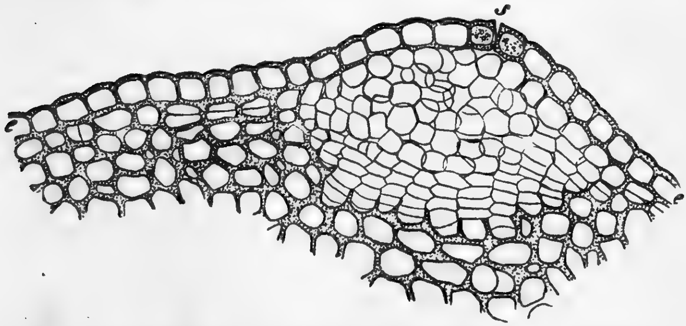


Fig. 113.—Transverse section through a lenticel of *Betula alba.* *e*, *e*, epidermis; *s*, old stoma; under this is a mass of cork which develops from the phellogen layer lying next to the ordinary parenchyma (figured darker); the great multiplication of cork-cells has pushed out the epidermis. × 280.—After De Bary.

the ordinary commercial article; the thick-walled form may be obtained from the bark of the beech, willow, prickly ash (*Xanthoxylum Americanum*), *Viburnum opulus*, etc. Its development may be observed by making successive sections of the shoots at different heights.

CHAPTER VIII.

INTERCELLULAR SPACES AND SECRETION RESERVOIRS.

160.—In addition to the cavities and passages which are formed in the plant from cells and their modifications, there are many important ones which are intercellular, and which at no time were composed of cells. In some cases they so closely resemble the cavities derived from cells that it is with the greatest difficulty that their real nature can be made out. In their simplest form they are the small irregular spaces which appear during the rapid growth of parenchyma-cells (Fig. 51, p. 67); from these to the large regular canals which are common in many water plants there are all intermediate gradations.

161.—In leaves, especially in the parenchyma of the under portion, there are usually many large irregular spaces between the cells; they are in communication with the external air through the stomata, and contain only air and watery vapor. The petioles and stems of many aquatic plants contain exceedingly large air-conducting intercellular canals, which occupy even more space than the surrounding tissues (Fig. 9, page 20). In the Water-lilies (*Nymphæaceæ*) and Water-plantains (*Alismaceæ*) they are so large as to be readily seen by the naked eye, and in the Naiads (*Naiadaceæ*) they are almost equally large (Fig. 114). In the fibro-vascular bundles of *Equisetum*, and of many Monocotyledons and some Dicotyledons, there are intercellular canals, sometimes of very considerable diameter (Figs. 99, 102, 103). Lastly, in the medullary parenchyma (pith) of many plants there is a large central cavity (although formed in part by the rupture of some cell-walls), which must be considered as inter-

cellular; of this nature are the cavities in many hollow stems —*e.g.*, in many Umbelliferæ and Gramineæ.

162.—There are in many plants intercellular spaces and canals, which are made the receptacles for special secretions, and to which the name of Secretion Reservoirs may be applied. They are surrounded (at first, at least) by secreting cells, which furnish the oil, gum, resin, and other substances (see p. 62) found in the reservoirs. Their structure and mode of development may be illustrated by the gum-canals of the Ivy (*Hedera helix*). Each at first consists of a long column developed in the phloëm, and composed of four or five rows of thin-walled cells arranged radially about a common axis. The cells soon separate from each other in the axis of the column, and thus form a small canal (Fig. 115, *A*), which is afterward increased in diameter by the formation of radial partitions, and the tangential growth of the surrounding cells (Fig. 115, *E*). The surrounding

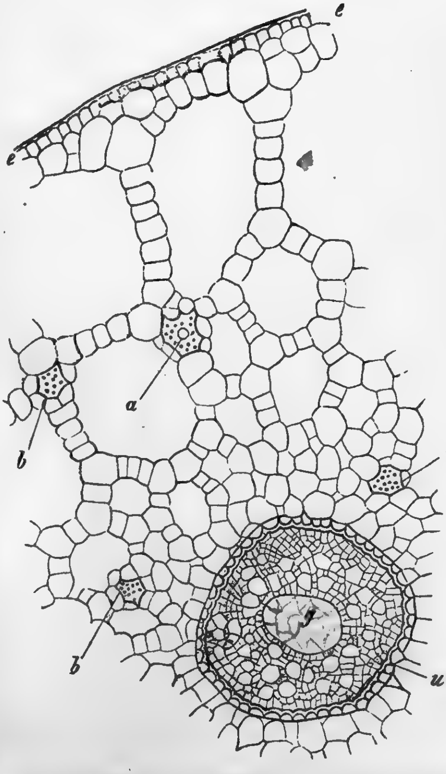


Fig. 114.—Part of the transverse section through the internode of the stem of *Potamogeton pectinatus*, showing the large intercellular spaces between the central fibro-vascular bundle and the circumference of the stem; *e*, *e*, epidermis; *a*, a small bundle consisting of surrounding fibrous tissue and a very small central mass of sieve tissue; *b*, *b*, *b*, small bundles containing only fibrous tissue; *u*, bundle sheath of principal bundle in the axis of the stem, within which is a mass of sieve tissue surrounding the intercellular canal, *g*. × 80.—After De Bary.

cells secrete a peculiar sap or gum, which passes into and fills up the canal.

In the Coniferæ the turpentine canals have essentially the same structure. They are found in the bark, wood and pith; they occasionally unite with one another, or change their direction through some of the medullary rays, the cells of which have apparently become transformed into resin-secreting tissue.

163.—Allied to the foregoing, although formed in a slightly different way, are the small secretion reservoirs of many plants, and in which oils, resins, gums, and other

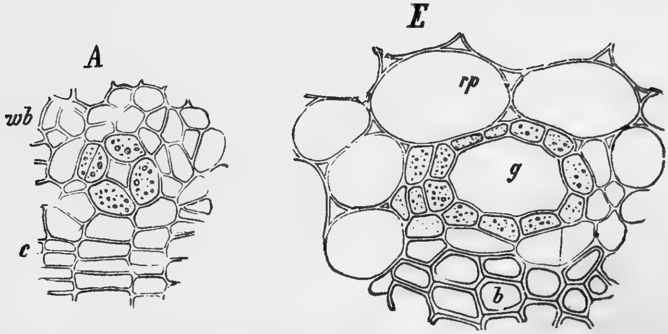


Fig. 115.—Transverse sections of young stem of Ivy (*Hedera helix*). *A*, young intercellular gum canal, surrounded by four cells; *c*, cambium; *wb*, soft bast; *E*, fully developed canal, *g*; *b*, bast; *rp*, cortical parenchyma. × 800.—After Sachs.

odorous substances are collected. The fragrance of many fruits—*e.g.*, oranges and lemons—is due to the oils and other matters contained in such receptacles. In *Dictamnus fraxinella* these are developed as follows: two mother-cells (*p, p*, Fig. 116) appear in the hypoderma and divide by several partitions, forming a mass of thin-walled secreting cells (Fig. 116, *B*); these, by a degeneration of their walls, fuse into a common cavity filled with oil and watery matter (Fig. 116, *C*). It appears that the outer layer of secreting cells (*c, c*) is developed from the epidermis (Fig. 116, *A, d, c*); hence this is partly an epidermal structure.

Of like nature are the reservoirs in the "glandular hairs" of the same plant; in fact, the two structures are apparently

but slightly different developments of the same organ (Fig. 117).

(*a*) The smaller and more irregular intercellular spaces may be studied in the fundamental tissue of the stem of Indian corn, in the parenchyma of most leaves, and the stems of *Juncus*.

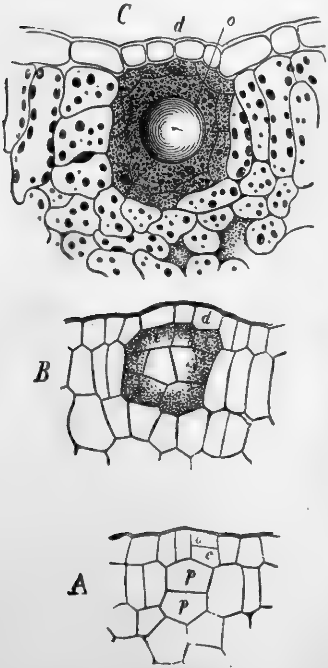


Fig. 116.

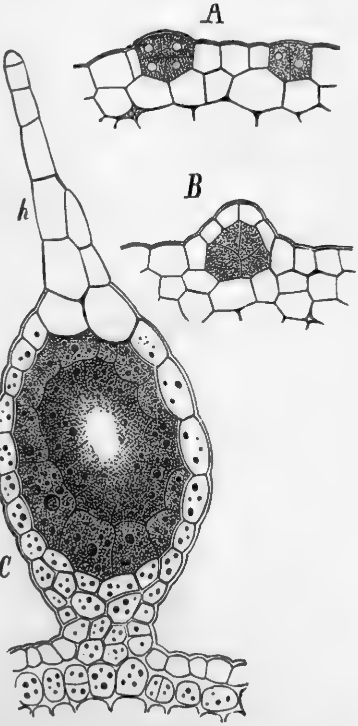


Fig. 117.

Fig. 116.—Internal glands of the leaf of *Dictamnus fraxinella*. *A* and *B*, early stages of development; *C*, mature gland; *d*, epidermis; *c*, *p*, mother-cells of the secreting cells; *o*, drop of ethereal oil.—After Rauter.

Fig. 117.—Glandular hair of the inflorescence of *Dictamnus fraxinella*; *A* and *B*, earliest stages, showing the origin to be similar to that of the internal glands; *C*, fully developed hair; the part *h* is the true hair, while all below it, including the oil cavity, is to be regarded as an outgrowth of the sub-epidermal cells. × about 220.—After Rauter.

(*b*) Thin cross-sections of the stems and petioles of *Nymphæa*, *Nuphar*, *Nelumbium*, *Sagittaria*, *Potamogeton*, and many other water plants, afford excellent specimens for the study of intercellular canals.

The relation of the intercellular spaces of the leaves to the canals of the petioles may be studied by carefully made longitudinal sections.

(c) The resin canals of *Silphium laciniatum* and *S. perfoliatum*, and the turpentine canals of Coniferæ, furnish excellent examples of the larger secretion reservoirs, while the smaller ones may be studied in the cavities in the rind of the orange and lemon, the leaves of *Dictamnus*, *Xanthoxylum*, Rue (*Ruta*), *Hypericum*, and many Labiatæ.

CHAPTER IX.

THE PLANT-BODY.

§ I. Generalized Forms.

164.—The cells, tissues, and tissue systems described in the preceding pages are variously arranged in the different groups of the vegetable kingdom to form the plant-body. The simplest plants are single cells or undifferentiated masses of cells; in those next higher the cells are aggregated into simple tissues, while still above these the tissues are grouped into tissue systems. With this internal differentiation there is a corresponding differentiation of the external plant-body. The lower plants are not only simpler as to their internal structure, but they are so as to their external form as well. The higher plants are as much more complex than the lower ones as to their external parts as they are in regard to their tissues and tissue systems.

165.—In the lowest groups of plants the simple plant-body has no members; the single-or few-celled alga has no parts like root, stem, or leaf; it is a unit as to its external form. In the higher groups, on the contrary, the plant-body is composed of several to many less or more distinct members. In those plants in which they first appear, the members are not clearly or certainly to be distinguished from the general plant-body; but in the higher groups they become distinctly set off, and are eventually differentiated into a multitude of structural and functional forms.

166.—As will be seen in the future chapters, every plant, in its earliest (embryonic) stages, is simple and memberless; and every member of any of the higher plants is at first indistinguishable from the rest of the plant-body; it is only in

the later growth of any member that it becomes distinct; in other words, every member is a modification of, and development from, the general plant-body. Likewise, where equivalent members have a different particular form or function, it is only in the later stages of growth that the differences appear. All equivalent members are alike in their earlier stages, whether, for example, they eventually become broad green surfaces (foliage leaves), bracts, scales, floral envelopes, or the essential organs of the flower.

167.—These facts make it necessary to have some general terms for the parts of the plant-body, which are applicable to them in all their forms. We must have, for example, a term so generalized as to include foliage leaves, bracts, scales, floral envelopes, and all the other forms of the so-called leaf-series. So, too, there is need of a term to include stems, bulbs, bud, and flower axes, root-stocks, corms, tubers, and the other forms of the so-called stem-series.

168.—By a careful study of the members of the more perfect plants we find that they may be reduced to four general forms, viz., (1) *Caulome,* which includes the stem and the many other members which are found to be its equivalent; (2) *Phyllome,* including the leaf and its equivalents; (3) *Trichome,* which includes all outgrowths or appendages of the surface of the plant, as hairs, bristles, root-hairs, etc.; (4) *the Root,* which includes, besides ordinary subterranean roots, those of epiphytes, parasites, etc.

169.—As indicated above, in the lower plants the differentiation into members is not so marked as in the higher. and in passing downward in the vegetable kingdom groups are reached in which it is inappreciable, and finally in which it is entirely wanting; such an undifferentiated plant-body is called a *Thallome,* and may properly be regarded as the original form, or prototype.

170.—Thallome.* The simplest thallome is the single cell; this, though generally rounded, is, in some cases (*Botrydium, Caulerpa,* etc.), irregularly extended into branch-like or leaf-like portions, which must not be mistaken

* From the Greek θαλλός, a young shoot, branch, or frond.

for members coördinate with those mentioned above, as they are only parts of a unit, instead of members of a body; they may be regarded as, to a certain extent, foreshadowings or anticipations of the members of the higher plants. Plants composed of rows of cells or cell surfaces frequently show no indication whatever of a division into members; but, in some cases, there is a little differentiation, which, though not carried far enough to give rise to members, is the same in kind. In the larger algæ there is sometimes so much of a differentiation that it becomes difficult to say why certain parts ought not to be called members. Caulome and phyllome, at least, are strongly hinted at in the Fucaceæ, and in this group, although the term thallome is applied to the plant-body, it must be admitted as not fully applicable. Structures of this kind are instructive, as showing that the passage from the thallome plant-body to that in which members are differentiated is by no means an abrupt or sudden one.

171.—Mutual Relations of Thallome, Caulome, and Phyllome. The caulome is the phyllome-bearing axis of the plant, and phyllomes are the members developed upon the caulome. The two have a reciprocal relation, and in no case is the one present without the other. The definition of the one involves that of the other. Both are derived directly from the thallome, and that differentiation which gives rise to one necessarily produces the other. The differentiation of thallome into caulome and phyllome is simply a lobing and contraction of the marginal portions into separable phyllomes, and a rounding and contraction of the central or axial portion into a caulome.

172.—Caulome.* By this general name we designate all axial members of the plant. In the more obvious cases the caulome is the axis which bears leaves (foliage), and in this form it constitutes (1) the *Stem;* branches are only stems which originate laterally upon other stems.

The other caulome forms are:

(2.) *Runners,* which are bract-bearing, slender, weak, and trailing.

---

* From the Greek καυλός, stem.

(3.) *Root-stocks,* which are bract or scale-bearing, usually weak, and subterranean.

(4.) *Tubers,* which are bract or scale-bearing, short and thickened, and subterranean.

(5.) *Corms,* which are leaf-bearing, short and thickened, and subterranean.

(6.) *Bulb-axes,* which are leaf-bearing, short and conical, and subterranean.

(7.) *Flower-axes,* which are bract, perianth, stamen, and pistil-bearing, short, and usually conical and aerial.

(8.) *Tendrils,* which are degraded, slender, aerial caulomes, nearly destitute of phyllomes.

(9.) *Thorns,* which are degraded, thick, conical, aerial caulomes, nearly destitute of phyllomes.

173.—Phyllome.* The phyllome is always a lateral member upon a caulome. It is usually a flat expansion and extension of some of the tissues of the caulome. Its most common form is (1) the *Leaf* (foliage), which is usually large, broad, and mainly made up of chlorophyll-bearing parenchyma.

The other phyllome forms are :

(2.) *Bracts,* which are smaller than leaves, generally green.

(3.) *Scales,* which are usually smaller than leaves, wanting in chlorophyll-bearing parenchyma, and with generally a firm texture.

(4.) *Floral envelopes,* which are variously modified, but generally wanting in chlorophyll-bearing parenchyma, and with generally a more delicate texture.

(5.) *Stamens,* in which a portion of the parenchyma develops male reproductive cells (pollen).

(6.) *Carpels,* bearing or enclosing female reproductive organs (ovules).

(7.) *Tendrils* and *Spines,* which are reduced or degraded forms, composed of the modified fibro-vascular bundles, and a very little parenchyma ; in the first the structures are weak and pliable, in the latter stout and rigid.

The altogether special modifications of the phyllome, as in *pitchers* and *cups,* will be noticed hereafter.

---

* From the Greek φύλλον, leaf.

174.—Trichome.* The trichome is a surface appendage consisting of one or more cells usually arranged in a row or a column, sometimes in a mass. Its most common forms are met with in (1) the *Hairs* of many plants. (See page 95.)

The other trichome forms are:

(2.) *Bristles,* each consisting of a single pointed cell or a row of cells, whose walls are much thickened and hardened.

(3.) *Prickles,* like the last, but stouter, and usually composed of a mass of cells below.

(4.) *Scales,* in which the terminal cell gives rise by fission to a flat scale, which soon becomes dry.

(5.) *Glands,* which are generally short, bearing one or more secreting cells.

(6.) *Root-hairs,* which are long, thin, single-celled (in mosses a row of cells), and subterranean.

(7.) *Sporangia* of Pteridophytes, some of whose interior cells develop into reproductive cells (spores).

(8.) *Ovules* of Phanerogams, one or more of whose cells develop into reproductive cells (embryo sacs).†

175.—Root. The root is that portion of the plant-body which is clothed at its growing point with a root-cap. In ascending through the vegetable kingdom roots are the latest of the generalized forms to make their appearance, and in the embryo they appear to be formed later than caulome and phyllome. They present fewer variations than any of the other generalized forms. The ordinary (1) *Subterranean roots* of plants are typical. They differ but little from one another in all the groups of the Pteridophytes and Phanerogams.

The other root forms are:

(2.) *Aerial roots,* which project into the air, and often have their epidermis peculiarly thickened, as in the epiphytic orchids.

(3.) *Roots of Parasites,* which are usually quite short, and

---

* From the Greek θρίξ, τριχός, a hair.

† It is held by some botanists that in some plants the ovule is "the terminal portion of the axis," and that in others it is a leaf or part of a leaf.

in some cases provided with sucker-like organs, by means of which they come into a more intimate relation to their hosts.

176.—Particular Relations of Phyllome to Caulome. Sachs* has formulated the relations of phyllome to caulome in substance as follows:

(1.) Phyllomes always originate from the Primary Meristem of the punctum vegetationis; fully differentiated tissues are incapable of producing them.

(2.) They are always exogenous formations; that is, they

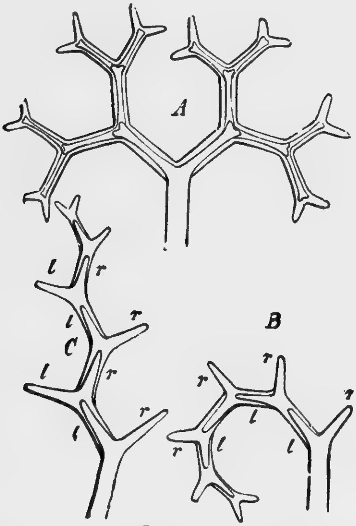


FIG. 118.

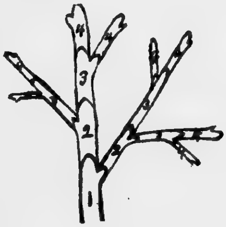


FIG. 119.

Fig. 118.—Diagrams of dichotomous branching. *A*, normal dichotomy, in which each branch is again dichotomously branched; *B*, helicoid dichotomy, in which the right-hand branch, *r*, does not develop further, while the left-hand one, *l*, is in every case again branched; *C*, scorpioid dichotomy, in which the branches are alternately further developed.—After Sachs.

Fig. 119.—Diagram of botryose monopodial branching. The numerals indicate the "generations."

develop from outer and not inner tissues, consequently their tissues are externally continuous with those of the caulome.

(3.) They always originate below the growing apex of the caulome as lateral outgrowths; they may appear singly, so that no two are situated at the same height on the stem, or two or more may grow at once, generally at equal distances from one another in the circumference of the caulome.

* "Text-Book," p. 131.

(4.) They always arise in acropetal* order.

(5.) They grow more rapidly than the caulome does above their insertion. When they are numerous their rapid growth gives rise to the accumulation of phyllomes known as a *Bud.*

(6.) The phyllomes of any plant are always of a different form than the caulomes.

177.—General Modes of Branching of Members. There are two general modes of the branching of the members of the plant-body. In the one, the apex of the growing member divides into two new growing points, from which branches proceed; this is the *Dichotomous* mode of branching (Fig. 118). In the other, the new growing points arise as lateral members, while the original apex of the parent stem still retains its place and often its growth; this is the *Monopodial* mode of branching (Fig. 119). Both modes are subject to many modifications, the most important of which are briefly indicated in the following table:

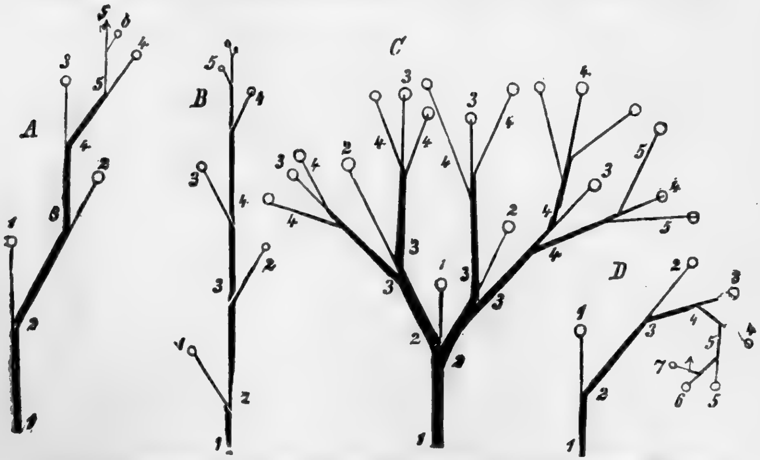


Fig. 120.—Diagrams of cymose monopodial branching. *A* and *B*, scorpioid cymes; *C*, forked cymose monopodium, the compound or falsely dichotomous cyme (called also the *dichasium*): *D*, helicoid cyme.—After Sachs.

A.—DICHOTOMOUS.

1. *Forked dichotomy*, in which both branches of each bifurcation are equally developed (Fig. 118, *A*).

---

* Acropetal, tending toward the summit; from the Greek ἄκρα, summit, and πετάω, to move toward.

2. *Sympodial dichotomy,* in which one of the branches of each bifurcation develops more than the other.
   a. *Helicoid sympodial dichotomy,* in which the greater development is always on one side (Fig. 118, *B*).
   b. *Scorpioid sympodial dichotomy,* in which the greater development is alternately on one side and the other (Fig. 118, *C*).

B.—MONOPODIAL.

1. *Botryose monopodium,* in which, as a rule, the axis continues to grow, and retains its ascendency over its lateral branches (Fig. 119).
2. *Cymose monopodium,* in which the axis soon ceases to grow, and is overtopped by one or more of its lateral branches.
   a. *Forked cymose monopodium,* in which the lateral branches are all developed (Fig. 120, *C*).
   b. *Sympodial cymose monopodium,* in which some of the lateral branches are suppressed ; this may be
      b′. Helicoid, when the suppression is all on one side (Fig. 120, *D*) ; or
      b″. Scorpioid, when the suppression is alternately on one side and the other (Fig. 120, *A* and *B*).

Dichotomous branching takes place in many Thallophytes; it is beautifully seen in the appendages to the perithecia of many Erysiphaceæ (*e.g.*, lilac-blight, cherry-blight, etc.) It occurs also in the roots, stems, and leaves of many Pteridophytes, and the leaves and other phyllome structures of some Phanerogams.

Monopodial branching is, on the other hand, the general rule for all members of the plant-body in Phanerogams, and in Pteridophytes, Bryophytes, and Thallophytes very much of the branching is also of this kind.*

§ II. Stems.

178.—The primary stem of a plant first develops from the meristem tissue of the embryo ; its subsequent growth is a growth from the meristem of the punctum vegetationis, together with an intercalary growth of its newer parts. On account of the more rapid growth of its young leaves, it usually happens that the stem is terminated by, and appears to grow from, a bud ; in fact, it is a common statement that stems grow from buds. It will be necessary to examine the bud in detail.

---

* A full discussion of this subject would occupy more space than can be allotted to it in this book, and any attempt to cover the subject in a few pages would tend rather to confuse the student than to enlighten him. For a good account, the student is referred to Sachs' "Text-Book of Botany," p. 155; Hofmeister's "Allgemeine Morphologie der Ge-

179.—The *punctum vegetationis* (growing point) of a stem is generally a conical point; upon its curved surface a little below its apex the rudiments of leaves appear as slight swellings or papillæ; as the growing point elongates, and the rudimentary leaves grow, new ones appear above the previously formed ones. By the more rapid growth of the leaves than the newer part of the stem, the latter comes to be covered with many closely approximated young leaves. This is the usual condition of the ends of growing stems in summer, hence such an aggregation of rudimentary leaves may be termed a summer bud. While in the apex of the bud the leaves grow more rapidly than the stem, in its base the growth of the stem is much the most rapid. This later stem-growth is an intercalary one, and it results in separating the previously approximated leaves a considerable distance from one another, forming the internodes of the stem.

Fig. 121.—Extremity of a branch of the Horse-chestnut (*Æsculus hippocastanum*); a large terminal bud with two smaller lateral buds; *a*, *a*, *a*, scars of fallen leaves. Natural size.—After Duchartre.

180.—Winter buds have essentially the same structure, and the same mode of formation. In these, however, most of the phyllome rudiments develop into more or less hardened scales, which grow rapidly and overtop the punctum vegetationis. The basal growth of the bud ceases, and soon its apical growth also, and thus the scaly phyllomes are left in close approximation (Fig. 121). Such a bud is but a state of the terminal portion of the leaf-bearing stem, and not a new formation or member; it cannot even be called an organ.

181.—Upon the return of warm weather in the spring

---

wächse," p. 432, and Eichler's "Blüthendiagramme," page 33 *et seq.* In each there are many references given to the literature of the subject.

the basal growth of the bud is resumed, and shortly afterward, or simultaneously, the apical growth also. The thick scales separate by the slight elongation of the stem, and being of no further use to the plant they soon fall off. The intercalary growth of the scale-bearing portion of the stem is generally much less than of that which bears leaves, hence the first internodes which appear in the spring of the year are quite short. The punctum vegetationis of such a winter bud, after resuming its activity, goes on developing leaves as lateral members exactly as if there had been no interruption in its activity. Upon the approach of autumn again the

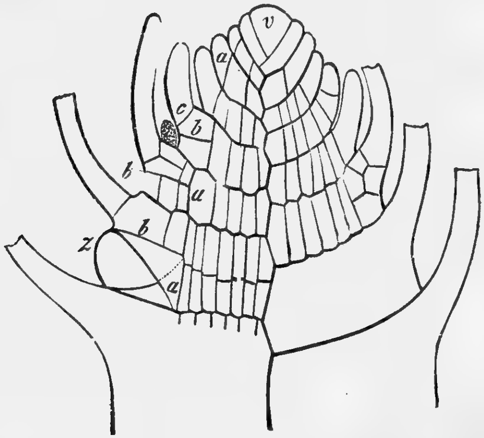


Fig. 122.—Longitudinal section of the apex of the stem of a moss (*Fontinalis antipyretica*). *v*, apical cell; *a*, outer part of one of the segments cut off from apical cell; *z*, apical cell of a lateral leaf-bearing shoot arising below a leaf; *c*, first cell of a leaf; *b*, *b*, cells forming cortex.—After Leitgeb.

same process of bud-formation takes place by the decrease in the rapidity of extension, and its final cessation; this is followed again by the resumption of growth upon the advent of spring. Thus the stem exhibits a periodicity in its growth, and one of its phases is the so-called winter bud.

182.—Branches of stems (lateral stems) normally originate in the punctum vegetationis as lateral outgrowths (Fig. 122, *z*); each develops first into a conical mass, which then becomes the punctum vegetationis of a new stem, and upon it lateral members arise, as in the case of the principal stem. The new stem may elongate at once into a leafy shoot, as

takes place in annuals; on the other hand, it may make but little growth in extension, so forming a bud, as is common in perennials (Fig. 123). Buds like the last, which are apparently sessile upon the parent axis, are said to be lateral, although, strictly speaking, they are terminal upon very short stems.

183.—It most frequently happens that new stems arise near to certain leaves. The origin of the stem may be below the leaf, as in many Bryophytes (*z*, Fig. 122); or beside it, as in Equisetaceæ; or above it in its axil, as in Monocotyledons and Dicotyledons (Fig. 121), and it appears that in each case the new stem originates shortly after the leaf.

184.—In Monocotyledons and Dicotyledons there are usually as many new stems formed as there are leaves; exceptionally there may be several new stems (supernumerary stems or buds) formed in the axil of each leaf (Fig. 123.) In mosses, ferns, and Conifers, on the contrary, there are by no means as many new stems as there are leaves.

185.—Rarely, new stems (adventitious stems or buds) arise from the older parts of plants; thus they may arise from petioles and ribs of some leaves—*e.g.*, *Begonia*, *Bryophyllum*, etc.; from the cambium of the cut surfaces of stems — *e.g.*, elm, willow, etc.; and sometimes in abundance from the fibro-vascular bundles of roots—*e.g.*, *Populus alba*, cherry, sweet potato, etc. Such structures are always endogenous, as in all cases they spring from some portion of, or near to, the fibro-vascular bundles, and break through the overlying tissues.

Fig. 123.—Branch of the Cherry bearing lateral buds; *b'*, *b'*, *b'*, buds from which leafy branches will develop; *b*, *b*, *b*, buds from which flowers will develop. Natural size.—After Duchartre.

186.—Frequently the new stems which are normally formed make but a very little growth, and in perennials become covered by the subsequently formed tissues; they thus become the so-called dormant buds. Under favorable conditions they may resume their growth long afterward, and they are then liable to be mistaken for adventitious stems. Probably very many of the supposed cases of adventitious stems upon the older stems of Dicotyledons are in reality only the late growths of stems which have been dormant for a long time.

(*a*) The development of stems may be studied in almost any plant. Those which have large winter buds, however, offer some advantages to the beginner. Such are the buds of hickory, horse-chestnut, lilac, etc.

(*b*) Vertical sections should be made of the buds before they resume their growth in the spring, and these should be compared with similar sections made after some growth has taken place.

(*c*) Many of the common annuals with a continued growth—*e.g.*, balsam, mallow, etc.—may be profitably studied for making out the growth of summer buds. The young shoots of many shrubs—*e.g.*, elder and lilac—are also excellent for study.

(*d*) Thin enough longitudinal sections should be made to show the punctum vegetationis. The specimens may often be made much more instructive by coloring with carmine, or other staining fluids.

§ III. Of Leaves in General.

187.—Every leaf originates in the Primary Meristem of the punctum vegetationis. It is at first a small projection or papilla, composed of one or more cells, which undergo a rapid division, thereby producing the quick early growth before mentioned (p. 139). Generally the multiplication of the cells is such as to give rise to a surface whose plane cuts the stem transversely. In many cases the apex of the leaf soon becomes changed into permanent tissue while the base continues to grow, indefinitely in grasses and many other Monocotyledons, and definitely in most Dicotyledons. In other cases the base passes over into permanent tissue, while the apical portions keep on growing, as in ferns and some pinnate leaves of Dicotyledons.

188.—Many leaves are raised upon a stalk by a subsequent growth between the stem and the base of the leaf; this leaf-

stalk (petiole) is much extended in the lower leaves of many plants, especially of those which grow in the shade or are intermixed with other plants. Structurally the petiole is the extension of the fibro-vascular and parenchymatous connection between the leaf and the stem; and it generally forms an articulation or joint with the stem at its lower extremity; physiologically it is a support for the leaf, and it is longer or shorter just as elongation or want of it places the leaf under the best physiological conditions.

189.—The leaf is, when first formed, destitute of fibro-vascular bundles, and this is the permanent condition of the leaves of Bryophytes, and the leaf-like portions of the Thallophytes. In most higher plants, however, portions of the leaf tissue early become differentiated into one or more fibro-vascular bundles, which pass downward into the stem and unite with the older bundles; the upper parts of the bundles grow with the leaf, and form lateral branches and branchlets, giving rise to the complicated system of so-called veins so often to be seen (especially in Dicotyledons). In many of the smaller phyllome structures, as scales, bracts, etc., which may be regarded as rudimentary leaves, there are no fibro-vascular bundles, just as in the rudiments of actual leaves.

190.—*Venation.* In mosses and other plants destitute of fibro-vascular bundles, the veins, when present, are composed of but slightly modified parenchyma; in higher plants they are composed of fibro-vascular bundles and, in the larger veins, of one or more surrounding layers of modified parenchyma in addition. The disposition of the veins in a leaf depends largely upon its mode of growth. Usually several veins form early; if they grow from a common point, an arrangement like that in the maple (*radiate* venation) is the result; if the veins grow from points on an axis, the various modifications of the *pinnate* venation are produced, depending upon the amount of elongation of the axis.

In many Monocotyledons the leaves continue to grow at their bases; their veins are, as a consequence, parallel with the leaf axis; in other Monocotyledons and most Dicotyledons the veins originate on an extending axis, and pass outward to or near to the margins.

191.—Leaves are for the most part bilaterally symmetrical, a vertical plane passing from base to apex generally dividing them into two equal and corresponding halves. In the elm, linden, begonia, etc., and the leaflets of many compound leaves, the two halves are unequal. The asymmetry is apparently related in some way to the position of the leaves on the stem, as it is more frequently noticed on plants whose leaves are two-ranked, with the leaf planes parallel, or nearly so, to the axis of the stem (or in compound leaves, to the central leaf axis). In some two-ranked leaves the upper half of each leaf (*i.e.*, that nearer to the apex of the stem) is the larger, while in others the opposite is the case.*

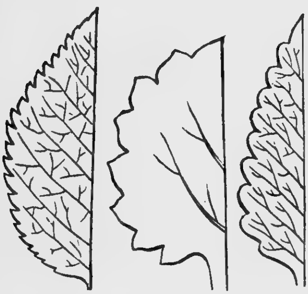


Fig. 124.—*A*, leaf with serrate margin; *B*, leaf with dentate or toothed margin; *C*, leaf with crenate or scalloped margin.

192.—In form leaves are very variable; even in the same plant it rarely happens that all have the same form. In general, elongated forms (*i.e.*, linear and oblong) prevail in the Monocotyledons, while as a rule they are considerably broadened (*i.e.*, lanceolate, elliptical, cordate, etc.) in mosses, ferns, and Dicotyledons; many exceptions, however, occur.

193.—The absolute size of leaves varies greatly also. The largest leaves—as, for example, those of palms, tree-ferns, banana, *Victoria regia*, etc.—occur in the warmer portions of the earth; in frigid regions the leaves are small; in temperate climates perennial leaves are, as a rule, smaller than annual ones.

* See an article on this subject by Professor Beal in *American Naturalist*, 1871, p. 571, and a still earlier one by Dr. Wilder. Both writers show that in many cases the upper half of the leaf is the most developed, in opposition to De Candolle, who makes the statement that "the side most developed is always the lower." Herbert Spencer's supposition that the want of symmetry is (in some cases) due to the shading of the smaller half of the leaf, they show not to be correct, as the asymmetry is observable in the young leaves in the unexpanded bud!

194.—Leaves, like other members of the plant-body, may branch during their growth. At first they are always simple, and if the growth is uniform the result is a simple leaf; if, however, as frequently happens, the growth is more rapid at certain points, branches may arise, as in the so-called compound leaves. All gradations are observable between simple leaves, in which the growth has been absolutely uniform (producing entire margins), to compound leaves with jointed leaflets. The differentiation is here much like that which takes place in passing from the thallome to the form of plant-body with distinct caulome and phyllome.

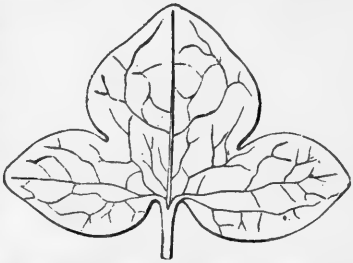
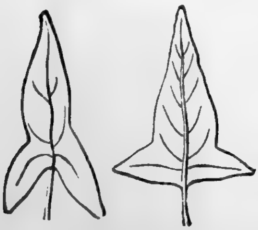


Fig. 125.—Three-lobed leaf of Hepatica.

The simplest cases are those in which the branches are rudimentary, as in the *serrate* (Fig. 124, *A*), *dentate* (Fig. 124, *B*), *crenate* (Fig. 124, *C*), and other similar forms. When the branches are more prominent they give rise to lobes of various kinds (Figs. 125, 126). Where the longitudinal growth of the leaf (not of its branches) is but little, the lobes appear to radiate from a common point, as in hepatica, mallow, maple, etc.; such are called *radiately, palmately*, or *digitately* lobed. Where, as in the oak, the longitudinal growth of the leaf is considerable, the lobes are laterally arranged upon a central portion; such leaves are said to be *pinnately* lobed.



A *B*

Fig. 126.—*A*, three-lobed sagittate leaf. *B*, three-lobed hastate leaf.

195.—Leaf-branches frequently become so developed that they themselves form distinct leaves, and thus we have what is termed the compound leaf (Figs. 127 and 128). Terms similar to those used in the case of lobed leaves are here used also; thus where the secondary leaves (leaflets) grow from an extremely short axis, so that they radiate from a

common point, the leaf is said to be *radiately, palmately,* or *digitately* compound (Fig. 127, *A* and *B*). In those cases where the leaflets grow from an axis which lengthens more

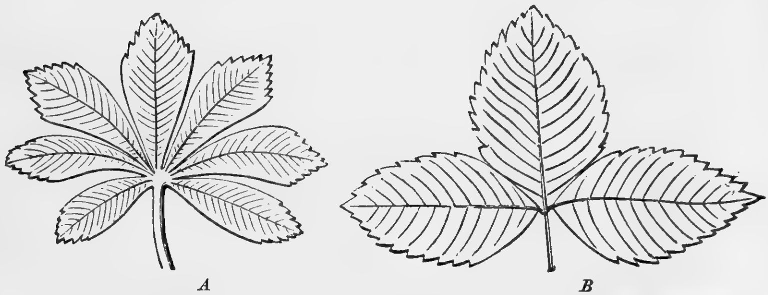


Fig. 127.—*A*, palmately compound leaf of Horse-chestnut; *B*, palmately trifoliate compound leaf.

or less, the leaf is termed a *pinnately* compound one (Fig. 128, *A* and *B*). It not infrequently happens that in the growth of leaflets they also produce branches, giving rise thus to doubly compound leaves.

Fig. 128.—*A*, pinnately compound leaf; *B*, pinnately compound leaf, with common midrib prolonged and metamorphosed into a tendril. (See page 136.)

196.—The stipules which occur as lateral appendages upon the petioles of many leaves of Dicotyledons are early leaf-branches which were not carried up by the subsequent elon-

gation of the petiole; as in the pea, vetch, agrimony, quince, etc.

§ IV. The Arrangement of Leaves (Phyllotaxis).

197.—Leaves are disposed on stems in various ways:

(1.) They may be in *whorls* of three or more encircling the stem at intervals. In this case each whorl was formed as a ring of rudimentary leaves about the punctum vegetationis.* The leaves of each succeeding whorl usually appear just above and between the preceding ones, so that the whorls alternate with one another.

(2.) Where two leaves originate on exactly opposite sides of, and at the same height on, the punctum vegetationis, the *opposite* arrangement is produced. Here, as in whorled leaves, the new ones usually arise in the intervals between the previously formed ones, so that the pairs of leaves decussate.

(3.) If the leaves originate singly (scattered or alternate leaves), the simplest case is that in which each succeeding leaf appears a little above the preceding and on the opposite side of the punctum vegetationis. In this case, where the stems elongate, the leaves are arranged in two opposite longitudinal rows or ranks (*orthostichies*),† hence this is called a *two-ranked* arrangement.

(4.) If, instead of each new leaf forming at a point half of the circumference of the punctum vegetationis from the last, it appears at a point distant (always in the same direction) one third of the circumference, there will be three vertical rows of leaves upon the stem; this is the *three-ranked* arrangement.

(5.) In rare cases the succeeding leaf is in each case distant one fourth of the circumference from the last, always measuring in the same direction; this gives rise to the *four-ranked* arrangement.

---

* There are some cases of false whorls, in which the leaves are first formed at different heights, and only later by irregularities in the growth of the stem become whorled.

† From the Greek ὀρθός, straight, and στίχος, a row.

(6.) It is very common for the young leaves to appear in succession on the punctum vegetationis at a distance equal to two fifths of the circumference from each, producing a *five-ranked* arrangement.

(7.) A *seven-ranked* arrangement is rarely seen; it is produced by the leaves following each other at a distance of two sevenths of the circumference.

(8.) An *eight-ranked* arrangement, which is a very common one, results from the leaves appearing at the constant distance of three eighths of the circumference.

(9.) In like manner there may be formed 9, 11, 13, 14, 18, 21, 23, 29, 34, 37, 47, 55, and 144 ranks.

198.—The distance between any two succeeding leaves is called the angular divergence; it may generally (but not always) be deduced directly from the number of ranks (orthostichies); thus in the 2-ranked leaves it is $\frac{1}{2}$; in the 3-ranked, $\frac{1}{3}$; in 4-ranked, $\frac{1}{4}$; in 5-ranked, $\frac{2}{5}$ (rarely $\frac{1}{5}$); in 7-ranked, $\frac{2}{7}$; in 8-ranked, $\frac{3}{8}$ (rarely $\frac{1}{8}$); in 9-ranked, $\frac{2}{9}$; in 11-ranked, $\frac{3}{11}$; in 13-ranked, $\frac{5}{13}$; in 14-ranked, $\frac{3}{14}$; in 18-ranked, $\frac{5}{18}$; in 21-ranked, $\frac{8}{21}$; in 23-ranked, $\frac{5}{23}$; in 29-ranked, $\frac{8}{29}$; in 34-ranked, $\frac{13}{34}$; in 37-ranked, $\frac{8}{37}$; in 47-ranked, $\frac{13}{47}$; in 55-ranked, $\frac{21}{55}$; in 144-ranked, $\frac{55}{144}$.

Examples of the more common of these arrangements are to be found as follows.*

(*a.*) 2-ranked in *Fagus, Celtis, Ulmus, Vitis, Tilia,* most *Vicieæ,* and all grasses.

(*b.*) 3-ranked in *Carex, Scirpus,* and most *Jungermanniæ.*

(*c*). 4-ranked in the bracts of the principal axis of inflorescence of *Restio erectus* and *Thamnochortus scariosus.*

(*d.*) 5-ranked in *Quercus, Populus, Robinia,* most *Rosaceæ, Borraginaceæ,* etc.; this is the most common arrangement in Dicotyledons.

(*e.*) 7-ranked in *Melaleuca ericæfolia, Euphorbia heptagona, Sedum sexangulare,* etc.

(*f.*) 8-ranked in *Polytrichum, Parietaria erecta, Antirrhinum majus, Raphanus, Brassica, Hieracium pilosella,* etc.

(*g.*) 9-ranked in *Lycopodium selago.*

(*h.*) 11-ranked not rarely in *Sedum reflexum* and *Opuntia vulgaris.*

(*k.*) 13-ranked in *Verbascum, Rhus typhina, Tsuga canadensis.*

---

* This list of examples is from Hofmeister's "Allgemeine Morphologie der Gewächse," p. 448 et seq.

(*l.*) 21-ranked in the weak branches of *Abies pectinata* and *Picea excelsa*, and in most cones of these species.

(*m.*) 34-ranked on strong branches of *Abies pectinata* and *Picea excelsa*, cones of *Pinus laricio*, and the interfloral bracts of the inflorescence of *Rudbeckia.*

(*n.*) 55-ranked in the uppermost shoots of many pines and firs, in many *Mamillariæ*, etc.

(*o.*) 144-ranked in the interfloral bracts of strong-grown flower-heads of *Helianthus annuus.*

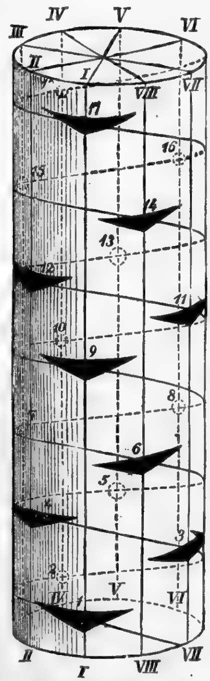


Fig. 129.—Diagram of eight-ranked arrangement. The orthostichies are marked at the top and bottom in Roman numerals, *I.* to *VIII*; the generating spiral may be readily followed from leaf to leaf, the latter being numbered from below upward.—After Prantl.

199.—By an examination of various leaf-arrangements, the following interesting but not very important facts may be noted (Fig. 129) :

(1.) If we draw a line from the insertion of one leaf to the one next above and nearest to it, and continue this around the stem to the next, and so on, a spiral will be obtained agreeing with the order of development of the young leaves on the punctum vegetationis. To this line, so drawn, the name of Generating Spiral has been given.

(2.) In most cases the spiral passes more than once around the stem before intersecting leaves of all the ranks.

(3.) The number of turns of the spiral about the stem in intersecting leaves of all the ranks equals the numerator of the fraction which indicates the angular divergence of the leaves from each other.

(4.) Two sets of secondary spirals (*Parastichies*)* crossing each other at an acute angle may be observed on the stem when the leaves are close together, as in Fig. 129; the leaves numbered 1, 6, 11, and 16 form one of the

* It is of great importance that the student should not regard these spirals (generating spirals and parastichies) as anything more than convenient means for describing any particular leaf-arrangement. Entirely too much attention has been given to working out all kinds of curious mathematical laws, which are, to say the least, absolutely worthless

parastichies passing to the right, while leaves 3, 6, 9, 12, 15, 18 belong to the parastichies which pass to the left.

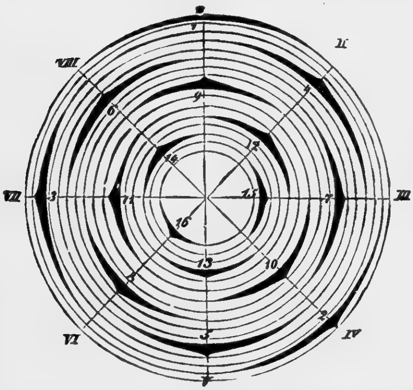


Fig. 130. — Diagram of eight-ranked arrangement, viewed from above. The orthostichies, which here appear to be radial lines, are numbered, as in Fig. 129, from *I.* to *VIII.* The leaves are numbered from 1 to 16.—After Sachs.

(5.) Upon counting, in Fig. 129, it is found that there are three parastichies passing to the left and five to the right; the smaller number is the same as the numerator of the fraction expressing the angular divergence, while the sum of the two equals the denominator; similar relations may be shown to exist in other cases.

200. — If now we study the several arrangements by projecting the stem upon a flat surface in such a way that the successive nodes, in ascending the stem, are represented by smaller and smaller concentric circles (Fig. 130) (as would, in fact, be the case if we made sections through the nodes of the punctum vegetationis), it is at once evident that each leaf is so placed as to stand over the vacant space between the previously formed ones, and that as regards the leaves formed after it, it is equally well situated.

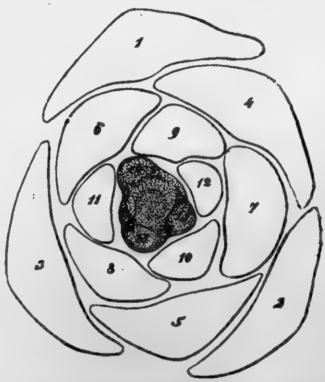


Fig. 130*a*.—Cross-section of a leaf-bud of the Hemlock Spruce (*Tsuga Canadensis*). Magnified.—After Hofmeister.

Hofmeister formulates this

---

to the morphologist. So much has this been done, that the study of Phyllotaxis has in some quarters become little more than a species of mathematical gymnastics.

as follows :* "New lateral members have their origin above the centre of the widest gaps which are left at the circumference of the punctum vegetationis between the insertions of the nearest older members of the same kind;" and no doubt this is one of the most important immediate causes which determine where each new leaf is to arise. If it be asked why, then, are not all leaves arranged alike, the answer must be looked for in the differences in structure of the *puncta vegetationes.* In cases where there is an apical cell, the arrangement of the leaves may be directly traced to its mode of division. In Phanerogams it is often clearly due

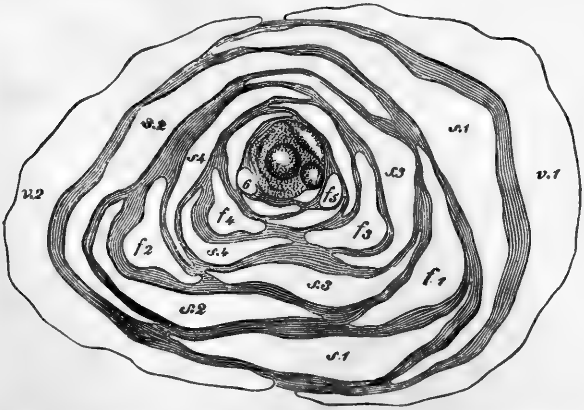


Fig. 130*b*.—Cross-section of the leaf-bud of the chestnut (*Castanea vesca*). v^1, v^2, the scale-like leaves; f^1, f^2, f^3, etc., the rudimentary leaves; s^1–s^1, s^2–s^2, etc., the stipules belonging to the correspondingly numbered leaves. Magnified.—After Hofmeister.

to a difference in the size and form of the punctum vegetationis; in Conifers and Composites, for example, it is common for a change in the arrangement to take place in passing from the foliage leaves to the bracts of the inflorescence upon the same stem, the number of ranks in such cases being greater on the larger axes. Doubtless some of the differences can be explained only by taking into account, also, the inherited peculiarities of the plant.

* "Allgem. Morphol.," p. 482, and quoted in Sachs' "Text-Book," p. 177.

A study of actual cross-sections of leaf-buds will make the truth of the previous statements more clearly evident. Hof-

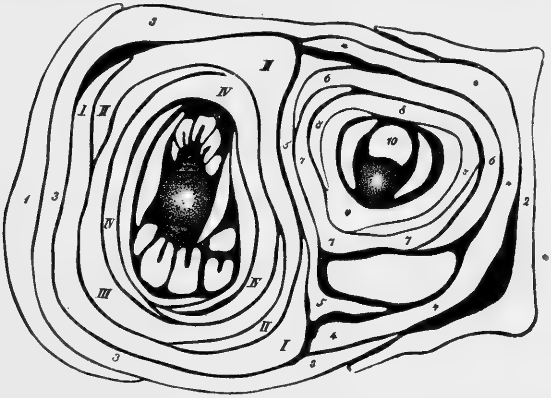


Fig. 130c.—Cross-section of a lateral bud of the Virginia Creeper (*Ampelopsis quinquefolia*), showing arrangement of parts in a double bud. Magnified.—After Hofmeister.

meister's figures,* several of which are here reproduced (Figs. 130, *a*, to 130, *d*), show that in all cases the leaf rudiments occupy in the bud the positions in which they meet with the least resistance. This is beautifully shown in the leaf-bud of the Hemlock Spruce (Fig. 130, *a*). In the leaf-bud of the chestnut (Fig. 130, *b*), the large stipules form the bud-scales ; but here, as in the preceding case, growth appears to follow the "lines of least resistance," the young leaves occupying the interspaces between the stipules. The double lateral bud

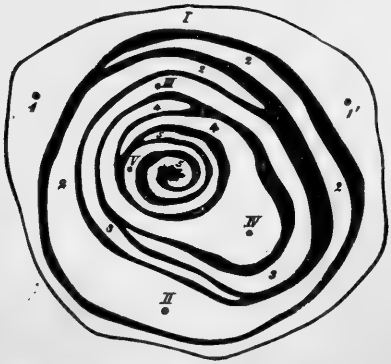


Fig. 130*d*.—Cross-section of the leaf-bud of a young plant of Indian corn (*Zea mais*). *I.*, the cotyledon, with its two fibro-vascular bundles, 1, 1′; *II.*, *III.*, *IV.*, *V.*, the successive leaves, their midribs marked by a dot. Magnified.—After Hofmeister.

* In "Allgem. Morphol."

of the Virginia Creeper (Fig. 130, *c*) may also be studied with profit, and it is curious to see how the positions of some of the leaves are altered by the fact that the bud is a double one. The bud of the Indian corn (Fig. 130, *d*) shows that the same law holds in the Monocotyledons as in the Dicotyledons.

§ V. The Internal Structure of Leaves.

201.—The internal structure of leaves varies considerably. In all cases, however, the leaf is composed mainly of thin-walled, chlorophyll-bearing parenchyma, and this is to be regarded as the proper leaf tissue. The fibro-vascular bundles constitute little more than the framework of the leaf and its connection with the stem, while the epidermis is here, as elsewhere in the plant, a covering tissue. In the related members of the plant, such as bracts, scales, floral envelopes, and other phyllome structures, chlorophyll-bearing parenchyma is generally wanting, but from true leaves it is rarely ever absent. The shape of the leaf, its size, position, and relation to other members, all have somewhat to do with securing the best disposition of the essential leaf tissue.

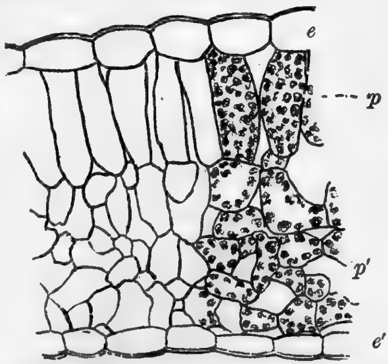


Fig. 131.—Vertical section of a portion of the leaf of *Echinocystis lobata*. *e*, epidermis of the upper surface; *e'*, epidermis of the lower surface; *p*, the parenchyma constituting the "palisade" tissue; *p'*, the loose and irregular parenchyma of the lower part of the leaf. In a part of the section the chlorophyll granules are shown. × 250.—From a drawing by J. C. Arthur.

202.—In leaves composed of one layer of cells, as in many mosses and some ferns, obviously there is no need of any special arrangement of the cells in order to secure their best exposure to light, heat, gases, etc. In thick leaves, however, the internal cells are clearly not so well situated as the external ones are, hence we find such leaves possessing some peculiarities in their structure which obviate this difficulty. Instead of being composed of solid tissues, their cells are

generally loosely arranged, with large intercellular spaces between them (Figs. 131 and 133), and these are in free communication with the external air by means of the stomata.

It most frequently happens that this loose tissue is in the under part of the leaf, while the upper portion is composed of one or more layers of closely placed cells; and this agrees with the general distribution of the stomata, there being usually many more on the under than the upper surface.

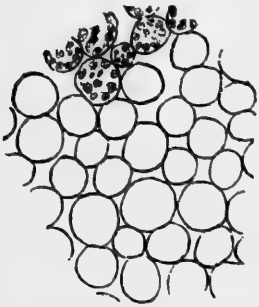


Fig. 132.—Section of the "palisade" tissue of the leaf of *Echinocystis lobata*, taken parallel to the leaf surface. A few of the cells drawn with their contained chlorophyll granules. × 250.—From a drawing by J. C. Arthur.

203.—The upper denser tissue, termed *palisade* tissue, is composed of elongated cells, which stand at right angles to the surface of the leaf (Fig. 131). In cross-section the palisade-cells are cylindrical, with small intercellular spaces between them (Fig. 132), or in some cases they are more or less compressed and angular.

In general, palisade tissue is confined to the upper surface of the leaf, the lower being occupied by the loose tissue previously mentioned; but there are some curious exceptions to this rule. The most notable of these is found in the leaf of *Silphium laciniatum*—the so-called Compass Plant *—of the Mississippi Valley; its chlorophyll-bearing parenchyma is almost entirely arranged as palisade tissue, so that the upper and lower portions are almost exactly identical in structure (Fig. 134). The vertical leaves of the Manzanita of the Pacific Coast (*Arctostaphylos pungens*, var. *platyphylla*) have a similar structure.

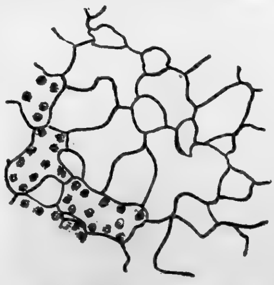


Fig. 133.—Section of the loose parenchyma of the leaf of *Echinocystis lobata*, taken parallel to the leaf surface. Several of the cells are drawn showing their chlorophyll granules. × 250.—From a drawing by J. C. Arthur.

* For descriptions of this curious plant, whose leaves have a marked tendency to stand with one edge to the north and the other to the

204.—Another curious leaf structure is to be seen in *Stipa spartea,* the Porcupine Grass of the interior; each long harsh leaf is longitudinally channelled on its upper surface, which, by the twisting of the basal portion of the leaf, becomes apparently the lower, and the chlorophyll-bearing parenchyma is confined to the sides of the channels (Figs. 135 and 136). At the bottom of each channel the epidermal cells are peculiarly developed into a hygroscopic tissue, which, by contracting, closes the channels and rolls the leaf together, as always takes place in dry air.

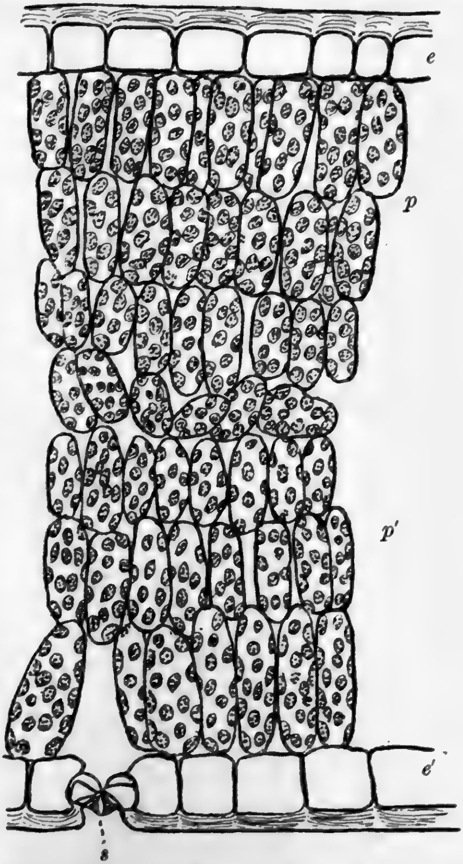


Fig. 134.—Transverse section of the leaf of *Silphium laciniatum.* *e*, epidermis of the upper surface; *e′*, epidermis of the lower surface; *p*, palisade tissue of the upper portion of the leaf; *p′*, palisade tissue of the lower part of the leaf; *s*, a stoma seen in transverse section. × 225.—From a drawing by the author.

(*a*) Many Monocotyledons—as, for example, Iris and Indian corn—afford good specimens of very young leaves. By carefully removing the outer leaves in succession all stages of leaf-development may be obtained.

---

south—*i.e.*, with the leaf-planes parallel to the plane of the meridian—see articles in the *American Naturalist:* 1870, p. 495; 1871, p. 1; 1877, p. 486.

In this way often much light will be thrown upon the morphology of leaf parts.*

(*b*) Among Dicotyledons it is generally best to select those whose young leaves are least downy or hairy, otherwise the difficulties of the examination are greatly increased. The lilac is one of the best for this purpose. Longitudinal sections, prepared as in the examination of young stems, should be made.

Fig. 135.—A part of a transverse section of the leaf of *Stipa spartea* in the position it assumes—*i.e.*, with what is really the upper surface turned toward the earth. *f*, *f*, ribs, each containing a fibro-vascular bundle; between these are the masses of chlorophyll-bearing parenchyma (figured dark in the cut). × 18.

(*c*) The young leaves in the winter buds of the hickory are instructive, as showing how compound leaves are formed.

(*d*) The study of the arrangement of leaves is most interesting in the twigs and cones of the Conifers, and the stems and heads of the Composites. The student should, however, before spending much time in the examination of the more difficult forms, study the twenty-sixth section of Sachs' "Text-Book of Botany," and the whole subject of the

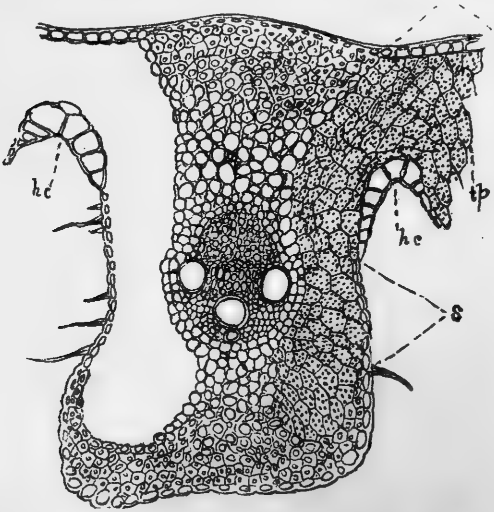


Fig. 136.—Transverse section of one of the ribs of the leaf of *Stipa spartea*. *tp*, chlorophyll-bearing parenchyma; *s*, *s*, portions of the epidermis containing stomata; *hc*, *hc*, hygroscopic cells, which contract when the leaf rolls up. The blank space on the left shows the extent of the cavity occupied by chlorophyll-bearing parenchyma. × 125.—From a drawing by the author.

* In illustration of this, the Iris itself may be cited. Its leaf is usually spoken of as made by the folding of its upper surface upon

arrangement of lateral members as given in Hofmeister's "General Morphology." *

(*e*) The internal structure of the leaf may be easily studied. The most important sections are those made at right angles to the surface; but some should be made also parallel to it, so as to show the form of the palisade cells and the dispositions of the cells in the loose tissue of the under surface. The leaves of the lilac, apple, cherry, *Impatiens*, *Silphium*, sunflower, etc., are very good for this study. The more difficult sections can be more easily made after soaking the leaves for some time in strong alcohol, thus hardening them.

§ VI. Of the Roots of Plants.

205.—The root differs from all other members of the plant in being tipped with a peculiar mass of cells—the Root-cap (*pileorhiza* †)—and in originating endogenously; from stems it differs in never producing leaves or other phyllome structures. There is some doubt as to whether the Primary Root—*i.e.*, the first root of the embryo—is not in many cases formed otherwise than endogenously; ‡ but all common roots certainly are developed from beneath the surface of other parts of the plant.

206.—Roots may develop from any part of a plant which contains fibro-vascular bundles, so that it is no uncommon thing for them to issue from stems (particularly their nodes) and leaves, as well as from other roots. Whatever their origin, they are essentially alike, the differences, as before intimated, being of minor importance. They all agree in hav-

---

itself, so that the two sides exposed to the air and light are said to be in reality the under surface. A study of the very young leaf of the *Iris*, along with that of *Hemerocallis*, shows them to be alike; both are composed of an upper laterally flattened portion and a lower channelled one; in the Iris the upper portion grows fully as much as the lower, while in *Hemerocallis* the growth is almost entirely confined to the lower portion, the upper extending but little and forming the small extremity of the leaf. The small tip of the leaf in the latter case is clearly the homologue of the whole of the so-called ensiform leaf of the former.

* "Allgemeine Morphologie der Gewächse," von Wilhelm Hofmeister; Leipsig, 1868.

† From the Greek πίλεος, a cap, and ῥίζα, a root.

‡ The mode of formation of the Primary Root will be taken up for each group of plants in Part II.

ing less perfectly developed tissues and tissue systems. Their epidermal system is more feebly developed, and they bear very

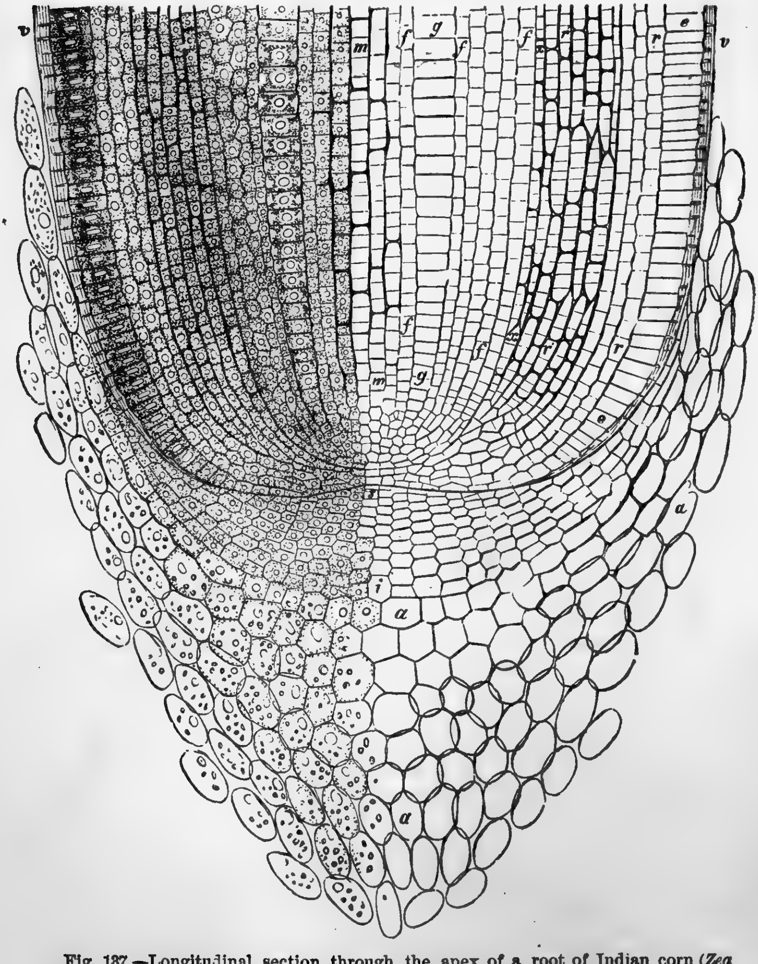


Fig. 137.—Longitudinal section through the apex of a root of Indian corn (*Zea mais*). All within and above the line *v, s, v*, is the root proper, all below and outside of it is the root-cap, or *pileorhiza*; *s*, apex of root; *e, e*, epidermis, continued into the dermatogen at the apex; *v, v*, the thickened outer wall of the epidermis (the origin of the root-cap from the dermatogen is not shown in this figure); *x, r*, the cortex which is produced from the periblem at the apex; *m, g. f*, the plerome; *m* becomes the pith, *g* a vessel, *f*, wood; *a, a*, outer and older portion of the root-cap; *i*, inner and younger portion of the root-cap.—After Sachs.

simple trichomes—the root-hairs. The fibro-vascular bundles are, especially in the higher plants, of a much lower type than those in the stems and leaves. The fundamental system is also poorly developed, and has not that variety of tissues found in other portions of the plant.

207.—Another remarkable peculiarity of roots is that they differ much less from one another in structure than do their stems. The young roots of Monocotyledons have very nearly the same structure that those of Dicotyledons have, and those of Pteridophytes do not differ much from either. The older roots of Monocotyledons and Dicotyledons differ considerably, on account of changes in their structure which take place later, and then each root bears a closer resemblance to the stem from which it grows, or to which it belongs.

208.—The general structure of the root-cap may be easily understood from the accompanying figure (Fig. 137). It is a cap-like mass of parenchymatous cells which surrounds the end of the root; its outer cells are loose, and in some cases are more or less changed into a mucilaginous mass; in any event they gradually lose their protoplasm and become detached and destroyed. The inner layers (*i*, *s*, Fig. 137) are constantly developing from a deep-lying tissue, the Dermatogen* (not shown in the figure), so that as the cap is destroyed on the outside it is renewed from the interior. By its lateral growth it in some cases ensheathes the terminal part of the root for a considerable distance.

209.—Back of the root-cap lies the primary meristem of the root, composed, in Phanerogams, of a mass of small and actively dividing cells. In this meristem there is as yet no differentiation, but as it is prolonged by rapid cell-multiplication the cells become modified in its posterior portion. There is thus a constantly advancing formation of meristem, followed at a little distance by as constant a modification into other tissues. The usual course of this differentiation is first into a central cylindrical mass, the *Plerome*† (Fig.

*** From the Greek δέρμα, δερματος, skin, and γέννάω, to bring forth or generate.**

† So named by Hanstein ("Scheitelzellegruppe im Vegetationspunkt der Phanerogamen," 1868), from the Greek πλήρωμα, a filling up.

137, *m, f, g*), which is ensheathed by the *Periblem*,* which soon becomes transformed into the cortical portion of the root (*x, r,* Fig. 137). The epidermis is developed from the region from which the root-cap grows, and, in fact, as will be shown below, it is a continuation and modification of the generating tissue of the root-cap.

210.—In Fig. 138 the relation of the parts is even better shown than in the previous figure. The central plerome column is surrounded by a layer of active cells, the pericam-

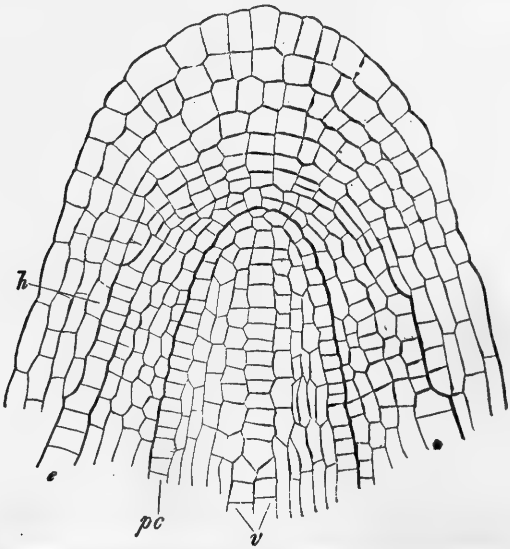


Fig. 138.—Median longitudinal section of the apex of the root of the buckwheat (*Fagopyrum esculentum*). *pc*, pericambium, constituting the boundary of the plerome column ; *e*, dermatogen ; between *e* and *pc*, periblem ; *h*, root-cap.—After De Bary.

bium (*pc*) ; outside of the latter lies the periblem, or young cortical portion, and still outside of this the dermatogen (*e*), which further back on the root becomes the epidermis. The root-cap (*h*) lies entirely outside of, and is quite distinct from, the back portions of the dermatogen, but near the apex of the root there is a tract in which dermatogen and root-cap apparently fuse into one. At this point the layers

*** Another of Hanstein's terms, from the Greek περίβλημα, a cloak.**

of the root-cap originate by the successive divisions of the dermatogen cells by partitions parallel to the curved surface of the root-tip. As the dermatogen is continuous with the epidermis, we may regard the root-cap as morphologically a greatly thickened and somewhat modified epidermis.

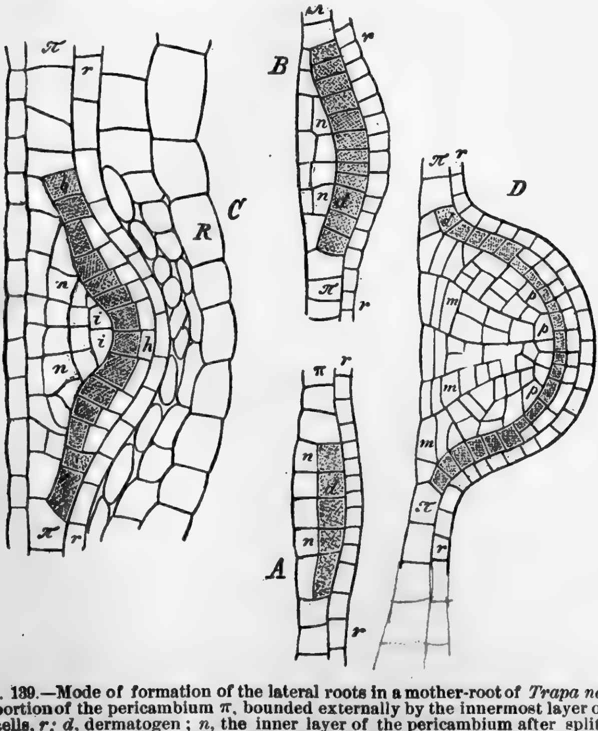


Fig. 139.—Mode of formation of the lateral roots in a mother-root of *Trapa natans*. *A*, a portion of the pericambium π, bounded externally by the innermost layer of cortical cells, *r*; *d*, dermatogen; *n*, the inner layer of the pericambium after splitting; *B*, the same advanced somewhat, the inner layer is beginning to divide; *C*, young root enclosed in the tissue of the mother-root; *R*, *r*, cortex of mother-root; π, pericambium of mother-root, from which the new root has been formed; *h*, first layer of the root-cap of the new root, formed by the splitting of its dermatogen *b*; *i*, *n*, mass of cells resulting from the division of the layer *n* in *A*; *D*, new root further developed (the thick cortical tissues of the mother-root are not shown; *r*, inner layer of cortical tissue of mother-root); *p*, *p*, periblem of new root; *m*, *m*, the tissue which connects the new root with the tissues of the mother-root. Magnified.—After Reinke.

The plerome column is a mass of nascent fibro-vascular elements, and in it, somewhat further back from the root-tip, a differentiation into the bundle takes place.

211.—The formation and development of a new root is interesting and suggestive. It usually takes place at some distance from the primary meristem, in the cambium or pericambium. In the root of *Trapa natans* it takes place as follows: The cells of a restricted portion of the pericambium divide by tangential walls into an outer layer, which becomes the dermatogen of the new root (*d*, Fig. 139), and an inner layer, from which develops its primary meristem (*n*, Fig. 139). The inner cells multiply by divisions in several directions, and as their mass increases they push out the young dermatogen (*B*, *C*, and *D*, Fig. 139). From the dermatogen the first layer of the root-cap is formed by the tangential division of its cells (*C*, *h*, Fig. 139). These growing tissues push out the overlying portions of the mother-root, and finally break through them. The root is thus seen to be a strictly endogenous formation; there is no connection between its tissues and the epidermal and cortical portions of the mother-root, the sole connection being with the deep-lying tissues in, or in connection with, the fibro-vascular bundles. Herein roots present a marked contrast to stems and leaves, which, as a rule, develop from the exterior of the plant-body, or, in other words, are exogenous in their origin.

212.—Roots are rarely arranged in as regular an order as are stems. In general they arise in acropetal order upon the mother-roots of Pteridophytes and the primary roots of Phanerogams, but this order is subject to many more disturbing influences than in the case of the origin of stems. As to position, they may arise in rows or ranks, or in particular spots, dependent upon the disposition of the fibro-vascular bundles, or the generating tissues in the root or stem. Thus it may happen that on a root or stem there may be as many rows of roots as there are fibro-vascular bundles. Roots which develop from stems are generally much more affected by external influences than those which grow from other roots. The degree of moisture of the different parts of the stem appears to have much to do in determining the point of the appearance of roots; this is seen in stems which touch the ground, as in the tomato, and in climbing plants, as the

Ivy (*Hedera*), Poison Ivy (*Rhus*), the Virginia Creeper (*Ampelopsis*), etc.

213.—In form roots are generally fibrous, and this is manifestly their best form, in so far as they are organs for obtaining dissolved matters from the soil. In perennials, however, as the stems become larger the roots increase correspondingly to support the additional weight; they thus become hold-fasts or mechanical supports. In other cases they are made the recipients of assimilated matters, as starch, sugar, etc., and thus become thickened storehouses.

In many cases the latter are capable of forming buds and of sending out new stems from the meristem tissue in, or in the vicinity of, the fibro-vascular bundles, as is notably the case in the tuberous root of the sweet potato.

(*a*) The root-cap may be studied with the least difficulty in roots which are grown in water. Those of *Lemna* may be easily obtained, and are excellent.

(*b*) Roots of Indian corn, Hyacinth, *Impatiens*, etc., also furnish easily made and good specimens.

(*c*) In preparing specimens for examination thin longitudinal sections should be made, and these should be supplemented by transverse sections taken at various heights on a root-tip.

(*d*) By the use of staining fluids, as carmine, magenta, etc., some points in the structure will be made more evident. Iodine should also be used; by treatment with it, the starch which is present in the root-tip in many, if not all, cases may be seen.

(*e*) For studying the formation and development of new roots succulent plants should be chosen, as the sections of their tissues are more transparent than those of other plants. On this account many water plants are to be preferred. Among land plants, *Impatiens* is one of the best; it always has a large number of forming roots on its stem near or at the surface of the ground.

(*f*) Vertical sections of the papillæ, showing the point of appearance of new roots, should be made. If many longitudinal slices of the lower part of the stem of *Impatiens* are made in a section-cutter, it will almost certainly happen that some good specimens will be found.

CHAPTER X.

THE CONSTITUENTS OF PLANTS.

§ I. The Water in the Plant.

214.—Amount of Water in Plants. All living parts of plants are abundantly supplied with water. It is always present in living protoplasm, and the greater its activity the more watery is its composition. The cell-walls of living tissues also contain large quantities of water; and in plants composed of many cells (as the larger flowering plants) even those cells and tissues which have lost their activity generally have their walls saturated with water. In ordinary herbaceous land plants the amount of water is not far from 75 per cent of their whole weight; thus in growing rye it is about 73 per cent; in meadow grass, before blossoming, 75—after blossoming, 69; in lucerne, when young, 81—in blossom, 74; in white clover, 80; in red clover, before blossoming, 83—after blossoming, 78; in oats, in blossom, 81; in Indian corn, in blossom, 84. In certain parts of plants the percentage is still higher; for example, in the leaves of the field beet it is 90; in tubers of the potato, 75; in the thickened root of the parsnip, 88; in the similar root of the turnip, 92. In aquatic plants the percentage is much higher, often exceeding 95; it is so abundant in many of the simpler forms that upon drying nothing but an exceedingly thin and delicate film is left.

215.—Water in the Protoplasm. As explained in paragraphs 4 and 5 (page 5), living protoplasm has the power of imbibing water, and thereby of increasing its fluidity. Even after it has imbibed all the water which it can retain it continues the process, and separates the surplus in drops

in its interior, the so-called vacuoles. Now an examination of the cells of rapidly growing tissues shows that their protoplasm is much more watery than that of living, but dormant tissues—*e.g.*, those of seeds—and one of the first signs of activity in the latter is the imbibition of water.

This avidity of protoplasm for water plays an important part in the general economy of the plant. By it all the cells which contain protoplasm are kept turgid, and by the tension thus created the soft parts of plants are made rigid. It plays no small part also in keeping up the supply of moisture in living tissues when wasted by evaporation. (See paragraph 220 et seq.)

216.—Water in the Cell-walls. In the cell-walls, according to Nägeli's theory, the water forms thinner or thicker layers surrounding the crystalline molecules of cellulose. (See paragraph 37, p. 32.) The wall of the cell is thus not a membrane which separates the water of one cell cavity from that in the next, but rather a pervious stratum, composed of solid particles which are not in contact, and between which the water freely passes. In a living tissue the water is continuous from cell to cell, and constantly tends to be in equilibrium—*i.e.*, the turgidity of the cells is approximately equal throughout the tissue, and likewise the wateriness of both cell-walls and cell-contents.

In the simpler aquatic plants the water of the cells and their walls is continuous with that in which they grow. Likewise the water in the tissues of roots or other absorbing organs of the higher aquatic plants is continuous with that which surrounds them; and even in ordinary terrestrial plants there is a perfect continuity of the water in the root tissues with the moisture of the soil.

217.—Water in Intercellular Spaces. In some cases the intercellular spaces and passages, and even the vessels of the more succulent plants, are filled with water, thus increasing its amount in the whole plant very considerably. More commonly, however, these cavities are filled with air and gases, the vessels having early lost the protoplasm which they contained at first. It is probable, moreover, that the

water which is occasionally found in their cavities has little or no physiological relation.

218.—The Equilibrium of the Water in the Plant. The water in the tissues of every plant tends constantly to become in equilibrium, and this state would soon be reached were it not for certain disturbing causes which are almost as constantly in action. In any cell an equilibrium may soon be reached between the two forces which reside respectively in the cell-wall and the protoplasm, viz., (1) the attraction of the surfaces of the molecules for the water, and (2) the "imbibition power" of protoplasm. This equilibrium once attained, all motion of the water must cease, and it must remain at rest until disturbed by some other force or forces. This condition, or one approximating very closely to it, is reached by many of the perennial plants during the winter or period of rest.

219.—Disturbance of Equilibrium. During the growing stages of plants the equilibrium of the water is constantly disturbed in one or more ways, viz., (1) by the chemical processes within the cells; (2) by the "imbibition power" of the protoplasm and walls of newly formed cells; (3) by the evaporation of a portion of the water.

The chemical processes within the cell include: (1) the actual use of water by breaking it up into hydrogen and oxygen; every molecule which is so broken up leaves a vacancy which, sooner or later, must be replaced; (2) the formation of substances which are more soluble than those from which they were formed; (3) the formation of substances which are less soluble than those from which they were formed. These processes take place in all cells, even those of the simplest plants.

In plants composed of tissues, wherever new cells are forming and developing, the new protoplasm and cell-walls require considerable quantities of water to satisfy their molecular attraction (paragraphs 215 and 216 above); this supply is always made in part or entirely at the expense of the adjacent cells. In many aquatic plants there can be little doubt that the needed water in meristem tissues is obtained partly by direct absorption from the surround-

ing water, but this can only be the case with the external cells; the deep-lying ones must obtain their supply from the cells which surround them. In aerial parts of plants the newly formed cells obtain all their water from the adjacent cells.

220.—Evaporation of Water. In the aerial parts of plants the evaporation of water from their surfaces is a far more powerful disturbing cause than either of the two preceding. Whenever a cell is exposed to dry air at ordinary temperatures a portion of its water passes off by evaporation; this immediately disturbs the equilibrium of water throughout the tissue, and the more rapid or the longer continued the evaporation, the greater the disturbance.

Evaporation (called also transpiration and exhalation) from living cells or tissues is dependent upon a number of conditions, some of which are entirely exterior, while others are connected with the structure of the plant itself. Among the former, the most important is the condition of the air as to the amount of moisture which it contains. In air saturated with moisture no evaporation can take place;* but whenever the amount of moisture falls below the point of saturation, if the other conditions are favorable, evaporation takes place. The temperature of the air (and, as a consequence, that of the plant also) has some effect upon the rapidity of evaporation. It appears that there is an increase in the amount of water given off as the temperature rises; this may be due, however, to the fact that with such increase of the temperature of the air there is generally a considerable decrease in its moisture. The direct influence of light upon evaporation is also somewhat doubtful. While there can be no doubt that plants generally lose more water in the light than in darkness, it may be questioned whether this is not

---

* Many experiments, at first sight, seem to show that plants evaporate water in air saturated with moisture; but Knop has found ("Versuchs-Stationen," Vol. VI., p. 255) that, under similar conditions, moist pieces of paper or wood also evaporate water, thus showing that the air, instead of being saturated, lacked somewhat of being so.

mainly due to the increased heat and dryness which are common accompaniments of the increase of light.*

221.—In enumerating the internal conditions one general one must not be forgotten, which is, that the water in plant-cells contains many substances in solution, and consequently evaporates less rapidly than pure water, in accordance with well-known physical laws. Moreover, the attraction of the molecules of the cell-walls for the water layers counteracts, to a considerable extent, the tendency to evaporation ; and in the same manner, even to a greater extent, the water is prevented from passing off by the "imbibition power" of protoplasm. It is, in fact, impossible to deprive cellulose and protoplasm of their intermolecular water in dry air at ordinary temperatures.

In all the aerial parts of higher plants the epidermis offers more or less resistance to the escape of the water of the underlying tissues. This is mainly accomplished by the thick and cuticularized outer wall of the epidermal layer ; in many cases, especially in plants growing naturally in very dry regions, the epidermis consists of several layers of cells, which offer still more resistance to evaporation by being themselves filled with moist air only. Among the lower plants, the single reproductive cells (spores) are guarded against the loss of water by having their walls greatly thickened and cuticularized. Even in the lowest plants, the Slime Moulds (Myxomycetes), the naked masses of protoplasm, when placed in dry air, will contract into rounded masses, which then become covered with a somewhat impervious envelope (paragraph 23, *c* : page 21).

222.—The stomata of the green and succulent parts of higher plants control to a great extent the amount and rapidity of their exhalation. In leaves, for example, where, on account of its cuticularization, there can be but little evaporation through the epidermis, it is dependent upon the

---

* I am aware that some experiments made with plants in saturated and in dry air appear to show that in direct sunlight there is a rapid evaporation. I cannot, however, regard these experiments as conclusive.

number, size, and condition (*i.e.*, whether open or closed) of the stomata. As previously described (paragraph 130, p. 99), the stomata are placed over intercellular spaces, which are in communication with the intercellular passages of the plant. These spaces and passages are filled with moist air and gases, which, when the stomata are open, expand and contract with every change of temperature or atmospheric pressure, and thus permit the escape of considerable amounts of water; when, on the other hand, the stomata are closed, little or no escape of moisture is possible. The opening and closing of the stomata appear to depend upon the amount of light; they open more widely the greater the amount of light, and close almost completely in darkness. The amount of moisture on the surface of the epidermis appears also to affect somewhat the opening and closing of the stomata; when the epidermis is very dry the stomata are generally closed, and *vice versa.*

223.—The Amount of Evaporation. The conditions controlling evaporation are thus seen to be many and various. They never, or but very rarely, act singly, two or more of them usually acting together with varying intensity, so that the problem of the amount of evaporation taking place at any particular time is a complex and difficult one. All the observations yet made, and which have necessarily been upon a very small scale, indicate that the rate of evaporation is actually very slow. Thus Hales long ago found that the amount of water evaporated from a vine in twelve hours of daylight equalled a film only .13 mm. (.005 in.) thick, and having an extent as great as that of the evaporating surface; the amount from a cabbage in the same time equalled a film .31 mm. (.012 in.) thick; from an apple tree, .25 mm. (.01 in.) thick; from a sunflower in a day and a night, equal to a film .15 mm. (.006 in.) thick.* Müller found the rate of evaporation from the leaves of *Hæmanthus puniceus* to be only one seventeenth as rapid as that from an equal area of water during the same time. Sachs found the evaporation

* "Statical Essays: Vegetable Statics," by Stephen Hales. 1727. Fourth edition. 1769. p. 21.

from the leaves of the White Poplar to be about one third as rapid as from water. Unger places the evaporation from most leaves at about one third that from equal areas of water; in some cases, however, running as low as one fifth and one sixth.*

224.—Pfaff calculated the amount of water evaporated from an isolated oak tree during the growing season. The tree selected was a close-topped one 6⅔ metres (20 ft.) high, bearing about 700,000 leaves. The results were as follows:

May (14 days)...........	883	kilograms	= (1,944 lbs.)
June....................	26,023	"	= (57,250 "
July....................	28,757	"	= (63,265 "
August..................	21,745	"	= (47,839 "
September...............	17,674	"	= (38,882 "
October.................	17,023	"	= (37,450 "

The evaporation from each leaf was for the season of five and a half months (one hundred and sixty-seven days) .16 kilograms (.35 lbs.); allowing forty-eight square centimetres of surface to each leaf, this amounted to a layer of water 3.33 centimetres (1.31 in.) deep over the whole evaporating surface.†

225.—The Movement of Water in the Plant. It is clear, from what has been said, that in polycellular plants there must be a considerable movement of water in some parts, to supply the loss by evaporation. Thus in trees there must be a movement of water through the roots, stems, and branches to the leaves, to replace the loss in the latter. This is so evident that it scarcely needs demonstration; it can, however, be shown by cutting off a leafy shoot at a time when

---

* The three last statements and the following are given on the authority of Duchartre ("Éléments de Botanique," second edition, 1877, pp. 844 and 846).

† Pfaff found that the water evaporated during the season, when considered with reference to the area of ground covered by the tree top, was equal to a layer 5.39 metres high (212 inches). Observation had shown the annual rain-fall to be .65 metres (25.6 inches); so that the water evaporated from the tree was eight times the amount which fell upon the earth under it. The evaporation is very much less in dense forests than in isolated trees, but with every allowance it is sufficient in dry, hot seasons to quickly exhaust the moisture of the soil.

evaporation is rapid; in a short time the leaves wither and become dried up, unless the cut portion of the shoot be placed in a vessel of water; in the latter case the water will pass rapidly into the shoot, and the leaves will retain their normal condition. If in such an experiment a colored watery solution (as of the juice of Poke berries) be used instead of pure water, it will be seen that the liquid has passed more abundantly through certain tracts than through others, indicating that the tissues are not equally good as conductors of watery solutions. As would readily be surmised, the tissues in ordinary plants which appear to be the best conductors are those composed of elongated wood-cells, and it is doubtless through them that the greater part of the water passes. Furthermore, it is probable that the movement of the water is through the substance of the cell-walls, and not, at least to any great extent, through the cell cavities. According to this view, the force which raises the water, in some cases to the height of a hundred metres or more, is the attraction of the surfaces of the crystal molecules for the layers of water which surround them.

226.—The rapidity of the upward movement of water evidently varies directly as the rapidity of evaporation, and inversely as the area of the conducting tissue in transverse section. As both these factors are variable, it is impossible to give an average rate of movement. Sachs estimated the rate of ascent in a branch of the Silver Poplar, from which there was strong evaporation, at 23 cm. (9 in.) per hour. McNab, by watering plants with a solution of lithium citrate and then examining the ashes at successive points, found the rate in a Cherry Laurel to be 101 cm. (40 in.) per hour. Pfitzer obtained the astonishing result of 22 metres (72 ft.) per hour in the Sunflower; there is but little doubt, however, that this is entirely too high.

(*a*) In addition to the movements of the water described above, that which has been called root pressure requires a brief mention. If the root of a vigorously growing plant be cut off near the surface of the ground and a glass tube attached to its upper end, the water of the root will be forced out, often to a considerable height. Hales* noted a pressure

* Statical Essays, p. 114.

upon a mercurial gauge equal to 11 metres (36.5 ft.) of water when attached to the root of a vine (*Vitis*). Clark,* in a similar manner, found the pressure from a root of the birch (*Betula lutea*) to be equal to 25.8 metres (84.7 ft.) of water. This root pressure appears to be greatest when the evaporation from the leaves is least; in fact, if the experiment is made while transpiration is very active, there is always for a while a considerable absorption of water by the cut end of the root, due probably to the fact that the cell-walls had been to a certain extent robbed of their water by the evaporation from above. Root pressure is probably a purely physical phenomenon, due to a kind of endosmotic action taking place in the root-cells.

(*b*) The flow of water (sap) from the stems and branches of certain trees, notably from the Sugar Maple, appears to be due to the quick alternate expansion and contraction of the air and other gases in the tissues from the quick changes of temperature. The water is forced out of openings in the stem when the temperature suddenly rises; when the temperature suddenly falls, as at night, there is a suction of water or air into the stem. When the temperature is nearly uniform, whether in winter or summer, there is no flow of sap.

§ II. As to Solutions.

227.—The water in the plant holds in solution several substances, so that it is not water alone, but in reality a complex solution. Some of the substances in solution are solids, as the inorganic salts taken up from the soil or water, while others are gaseous, as the air and carbon dioxide taken up in the water by the roots, or absorbed by the leaves and there entering into solution in the water. The final use of these solutions will be spoken of further on; here it is only necessary to point out some of the more important general facts as to solution and diffusion:

1st. When a substance has entered into solution it still exists *as that substance*, and the water in which it is dissolved is in *one sense* pure. This is readily shown by driving off the water by heat, when the dissolved substance is again obtained in its original solid state.

2d. As soon as solution begins the process of diffusion

* In 1873, recorded in the Twenty-first Report of the Secretary of the Massachusetts State Board of Agriculture. See also further results by the same observer in the Twenty-second Report.

necessarily commences also ; this is the passage of the molecules of the dissolved substance through the water without a movement of the latter. Thus in perfectly quiescent water a substance may diffuse itself between the molecules of the latter to considerable distances, and this may take place in any direction, even when the substance is heavier than water ; thus common salt placed in the bottom of a tall vessel of water will dissolve and gradually diffuse throughout the whole.

3d. The rapidity of diffusion varies for different substances ; thus the diffusion rate of sugar is more than three times that of common salt (exactly as 365 to 116).

4th. Two or more diffusions may take place at the same time in the same fluid, and they may move in the same or in opposite directions.

5th. Diffusion continues until all parts of the solution contain equal quantities of the dissolved substance.

6th. If at any point in a solution the dissolved substance be removed in some way, as, for example, by the formation of a new salt by chemical reaction, there will be, as a consequence, a continued diffusion toward that point ; and if the new salt be a soluble one it must diffuse in every direction from the point of its formation. Thus the molecular movements may become quite complex.

§ III. Plant Food.

228.—The most important elements which are used in the nutrition of plants, or which, in other words, enter into their food, are Carbon, Hydrogen, Oxygen, Nitrogen, Sulphur, Iron, and Potassium. These all appear to be necessary to the life and growth of the plant, and if any of them are wanting in the water, soil, or air from which the plant derives its nourishment, death from starvation will soon follow. There are other elements which are made use of by plants, but as life may be prolonged without them, they are regarded as of secondary importance. In this list are Phosphorus, Calcium, Sodium, Magnesium, Chlorine, and Silicon.

229.—The Compounds Used. With the single exception of oxygen, the elementary constituents named above do not enter into the food of plants in an uncombined state; on the contrary, they are always absorbed in the condition of compounds, as water, carbon dioxide, and the

Nitrates		Ammonia.
Sulphates		Potash.
Carbonates	of	Lime.
Phosphates		Iron.
Silicates, or		Soda, or
Chlorides		Magnesia.

In addition to these, many organic compounds are absorbed in particular cases, as in those plants which live in decaying animal or vegetable matter (saprophytes), as well as those which absorb the juices from living plants (parasites).

230.—How the Food is Obtained.—In the case of aquatic plants, these compounds are taken into the plant-body by a process of diffusion from the surrounding water; in terrestrial plants the gaseous compounds, as carbon dioxide and carbonate of ammonia, are absorbed—at least in part—by the leaves directly from the surrounding air, while the solutions of these and the other compounds in the water in the soil find their way into the plant by diffusion.

230*a*.—How the Food is Transported in the Plant. Once within the plant-body, the food materials diffuse to all watery parts, in the case of the larger terrestrial plants rising through the stem to the leaves. By diffusion, there is a constant tendency toward an equal distribution throughout the plant of the solutions which enter it, and if there were no disturbing chemical reactions taking place, such a condition would in most plants be soon reached. It is quite probable, indeed, that this actually happens for certain substances which are found in solution in the soil or water, and which, entering plants, diffuse through them to all parts, but not being used they soon reach a state of equal diffusion, which is only slightly disturbed by the extension of the plant-body by growth. Doubtless the rapid diffusion of food materials throughout terrestrial plants is aided by the

evaporation of water from the leaves, thus causing a strong upward movement of the water which contains the various solutions of food matter. Moreover, there can be no doubt that the movement of the water in terrestrial plants, caused by the swaying and bending of the stems and branches, facilitates and hastens the diffusion of food materials.

CHAPTER XI.

CHEMICAL PROCESSES IN THE PLANT.

§ I. Assimilation.

231.—In many plants the food materials which are taken into the plant-body are of such a nature that they can be directly used by the protoplasm; thus in the saprophytes the solutions of organic compounds derived from the decay of animal or vegetable tissues are imbibed by the protoplasm and used by it as true food; and in the parasites the protoplasm and the juices of living tissues are directly used in a similar way. It is, furthermore, probable that in some of the lowest forms of vegetation, as in the Myxomycetes and Schizomycetes, the protoplasm is capable of making, to a limited extent, a direct use of some of the inorganic substances absorbed by them. For the most part, however, the principal food materials taken in by plants are such as cannot be directly used by protoplasm in either its vegetative or reproductive activity; thus neither water nor carbon dioxide is directly used as food by the protoplasm of ordinary green plants, but in all cases they undergo certain chemical changes, by which they are made suitable for use by protoplasm. To these preparatory changes, which fit the crude food materials for protoplasmic food, the general name of Assimilation has been given.

232.—It is impossible as yet to give a complete statement of all the processes in assimilation; the principal facts now made out appear to be as follows: In the chlorophyll-bearing portions of plants, carbon dioxide and water are decomposed, and from their component elements carbohydrates are at once formed. This decomposition and subsequent combination take place only in the granules or masses of

chlorophyll, and only in sunlight. Those parts of ordinary plants which are destitute of chlorophyll are entirely wanting in the power of assimilation, and likewise the chlorophyll-bearing portions are unable to assimilate in darkness. Carbon dioxide is probably decomposed into carbon oxide and free oxygen : $CO_2 = CO + O$. At the same time water is decomposed into hydrogen and oxygen : $H_2O = 2H + O$. The free oxygen atoms are exhaled, and by the union of carbon oxide and hydrogen, starch is in most cases formed; this appears as minute granules imbedded in the chlorophyll-bodies (Fig. 43, p. 52). In some plants no starch is formed in the chlorophyll, but oily or sugary matters which have nearly the same chemical significance. Assimilation is thus a deoxidizing process. Both water and carbon dioxide contain large quantities of oxygen, while in starch it is much less ; consequently, in the formation of the latter from the former, there must be a surplus of oxygen. This may be shown as follows :

$$\left.\begin{array}{l} 12\,CO_2 = \left\{\begin{array}{l} 12\,CO \ldots\ldots\ldots\ldots\ldots \\ 12\,O \end{array}\right. \\ 12\,H_2O = \left\{\begin{array}{l} 12\,O \\ 24\,H \ldots\ldots\ldots\ldots\ldots \end{array}\right. \end{array}\right\} \begin{array}{l} \\ 12\,O + 12\,O = 24\,O \text{ set free.} \end{array} = \overset{\text{starch}}{C_{12}H_{20}O_{10}} + 2\,H_2O$$

Here twelve molecules of carbon dioxide and twelve molecules of water produce one molecule of starch and two molecules of water (water of organization), while twenty-four atoms of oxygen are set free and permitted to escape from the cells into the surrounding air or water.

§ II. Metastasis.

233.—Its General Nature. The chemical changes just described, which constitute assimilation, take place only in chlorophyll-bearing plants, or parts of plants, and in these only in the sunlight. In cells which are destitute of chlorophyll, and in the chlorophyll-bearing ones in the absence of light, other chemical changes take place ; these, while differing much among themselves, agree in always being processes of oxidation, and changes of one organic compound into another. To these chemical changes, in order to distinguish

them from those of assimilation, the term *Metastasis** (or preferably *Metabolism*) has been applied.

It is even more difficult to give anything like a complete account of the processes of metastasis than of those of assimilation; all that can be done is to indicate the general nature of the chemical changes which are best known.

234.—Transformation of Starch. In darkness the starch which had previously formed in the chlorophyll-bodies at once undergoes changes which render it soluble, allowing it to diffuse to other parts of the plant with great freedom. The nature of these changes appears to vary somewhat in different plants, but they consist essentially in the transformation of the insoluble starch into a chemically similar but soluble substance. Glucose ($C_{12} H_{24} O_{12}$), inulin ($C_{12} H_{20} O_{10}$), and cane sugar ($C_{12} H_{22} O_{11}$) are the more common of the soluble substances so formed, and one or other of these may frequently be detected in the adjacent cells after the disappearance of the starch from the chlorophyll.

235.—The Nutrition of Protoplasm. These diffusing assimilated matters are imbibed by the protoplasm of the living tissues, and constitute its most important food. In connection with the nitrates and sulphates, also imbibed, they furnish the materials for the increase of protoplasmic substance in growing cells. The exact changes which take place in the formation of protoplasm are unknown, but it is probable that a portion of the soluble assimilated matter (glucose, inuline, etc.) is broken up by the action of oxygen into carbon dioxide and one of the organic acids (*e.g.*, oxalic acid); and the latter, by replacing the acids in the sulphates and nitrates, may set free the sulphur and nitrogen necessary to the formation of protoplasm. The occurrence of crystals of calcium oxalate in the tissues of many plants rather indicates the probability of this or a similar series of reactions.

---

* Literally "to place in another way," from the Greek *μετά* beyond, or over, and *ἱστάναι*, to place. We owe the present application of the word to Professors Bennett and Dyer, who used it as the equivalent of the German "Stoffwechsel" in their English translation of Sachs' "Lehrbuch."

236.—The Storing of Reserve Material. In many plants the surplus of assimilated matter is stored up in one or more organs as reserve material; thus in the potato the starch formed in the leaves in sunlight is, in darkness, transformed into glucose, or a substance very nearly like it, and in this soluble form it is diffused throughout the plant, and in the underground stems (tubers) is again transformed into starch. So in the case of many seeds a mass of reserve material is stored up, generally in the form of starch (*e.g.*, the cereal grains), and sometimes in the form of oily matters (*e.g.*, the seeds of Cruciferæ, Flax, Castor Bean, Cucurbitaceæ, etc.). In the storing of starch a notable feature of the changes which take place is the apparent addition and subtraction of one or two molecules of water; it is probable, however, that in the transformation of starch to glucose oxygen combines with some of the carbon, forming free carbon dioxide, as follows:

$$6\,(C_{12}\,H_{20}\,O_{10}) + 24\,O = 5\,(C_{12}\,H_{24}\,O_{12}) + 12\,CO_2.$$

The transformation of glucose to starch may be a simple process of breaking up of a molecule of the former into starch and two molecules of water, as follows:

$$C_{12}\,H_{24}\,O_{12} = C_{12}\,H_{20}\,O_{10} + 2\,H_2\,O.$$

In the storing of oily matters it is probable that these are formed at the expense of the starch, and that they are the results of subsequent deoxidation.

237.—The Use of Reserve Material. In the use of reserve material, as in the germination of a starchy seed, the starch appears to undergo a change exactly like that in its disappearance from chlorophyll. Here it is certain that oxygen is absorbed, and that carbon dioxide is evolved, while the starch is transformed into glucose (see the reaction above). Similar transformations doubtless take place in the use of the starch stored up in buds, twigs, stems, bulbs, etc. In the germination of oily seeds, after the absorption of oxygen, starch is (in many cases, at least) first produced, and from this the soluble sugar is formed. In any case, after the solution is attained the subsequent metastatic changes are

similar to those which follow the transformation of the starch of the chlorophyll.

238.—The Nutrition of Parasites and Saprophytes is similar to that of embryos, buds, bulbs, etc. Here assimilated materials are drawn from some other organism, and subsequently undergo metastatic changes. In some cases the parasitism is only partial, as in the mistletoe, where a part of the assimilated matter is formed in the parasite (which, therefore, contains chlorophyll), while a portion seems to be taken along with the mineral salts from the host plant. So, too, there are plants which are partially saprophytic in habit, deriving a part of their nourishment as saprophytes, while the remainder is elaborated by their chlorophyll. Many cultivated plants, as we grow them, are partially saprophytic, deriving a portion of their nourishment from decaying organic matter in the soil. The so-called Carnivorous plants, as Drosera, Dionæa, Sarracenia, Darlingtonia, Nepenthes, Utricularia, etc., are in reality partially saprophytic, obtaining a considerable part of their food materials from decaying animal matter.

239.—The Formation of Alkaloids. Among the most obscure of the metastatic changes are those which give rise to the alkaloids. These are compounds of carbon, hydrogen, nitrogen, and generally oxygen, in which the first two elements have approximately an equal number of atoms, while the last two have also a nearly equal but much smaller number.

The more important ones are the following:

Conia ($C_8 H_{15} N$,) from Conium.
Nicotine ($C_{10} H_{14} N_2$) from Tobacco.
Cinchonia ($C_{20} H_{24} N_2 O$) from Peruvian Bark.
Morphia ($C_{17} H_{19} N O_3 + H_2 O$) from the Opium Poppy.
Strychnia ($C_{21} H_{22} N_2 O_2$) from the seeds of Strychnos.
Caffeine ($C_8 H_{10} N_4 O_2 + H_2 O$) from Coffee and Tea.

These and many others occur in plants in combination with organic acids, such as: malic acid ($C_4 H_6 O_5$); tartaric acid ($C_4 H_6 O_6$); citric acid ($C_6 H_8 O_7$); oxalic acid ($C_2 H O_4$); tannic acid ($C_{27} H_{22} O_{17}$); quinic acid ($C_7 H_{12} O_6$); meconic acid ($C_7 H_4 O_7$). These acids are probably formed

by the oxidation of some of the saccharine or amylaceous substances in the plant. while the alkaloids with which they are combined appear to have some relation to the nitrogenous constituents of the protoplasm, and are possibly derived from them. From the fact that the alkaloids are formed more abundantly in those tissues which have passed the period of their greatest activity, it may be surmised that they are either compounds of a lower grade which are formed instead of the ordinary albuminoids, or the first results of the incipient decay of the cells.

240.—Results of Metastasis. In the preceding paragraphs it is seen that chlorophyll-bearing plants absorb carbon dioxide and exhale free oxygen, the former being decomposed in the chlorophyll granules in sunlight and the oxygen being set free as a consequence. In other words, the absorption of carbon dioxide and the exhalation of oxygen are connected with the process of assimilation. It is further seen that oxygen is absorbed and carbon dioxide evolved, as results of certain metastatic processes which take place in any tissues, whether possessing chlorophyll or not, and independently of the presence or absence of sunlight. In the sunlight the absorption of carbon dioxide to supply assimilation is so greatly in excess of its exhalation as a result of metastatic action, that the latter is unnoticed. In darkness, however, when assimilation is stopped, the exhalation of carbon dioxide becomes quite evident. So, too, with oxygen; in the sunlight the excess of its evolution is so great over its absorption that the latter was long unknown; but in the absence of light its absorption becomes manifest. Parasites and saprophytes, as well as those parts of ordinary plants which are wanting in chlorophyll, as flowers and many fruits, deport themselves in this regard exactly as chlorophyll-bearing organs do in darkness.

CHAPTER XII.

THE RELATIONS OF PLANTS TO EXTERNAL AGENTS.

§ I. Temperature.

241.—General Relations. The functions of plants are possible only between certain limits of temperature of the air, water, or soil, varying considerably for each species. In every plant there is a certain minimum temperature, below which all functional activity ceases; thus in most instances plants become inactive when the temperature approaches 0° Cent. (32° Fahr.). On the other hand, there is a maximum beyond which activity ceases; this ranges in different plants from about 35° to 50° Cent. (95° to 122° Fahr.). Between these two extremes is the temperature at which the greatest activity takes place; this has been termed the *optimum.*

In any particular plant, the maxima, optima, and minima are not exactly alike for all functions, some being performed at temperatures considerably above or below those at which others cease. It is furthermore to be observed that, in general, there is a simple suspension of activity at temperatures a few degrees below the minimum, whereas above the maximum the death of the organ ensues; in the former a restoration of the normal temperature is soon followed by a resumption of activity; in the latter the activity cannot be restored, even under the most favorable conditions.

242.—Absorption of Water as Affected by Temperature. The absorption of water and watery solutions is greatly affected by changes in the temperature of the absorbing organs, as the roots of the higher plants. Thus Sachs found "that the roots of the tobacco-plant and gourd no

longer absorb sufficient water to replace a small loss by evaporation in a moist soil, having a temperature of from 3° to 5° Cent. (37° to 41° Fahr.); the heating of the soil to a temperature of from 12° to 18° Cent. (53° to 64° Fahr.) sufficed to raise their activity to the needful extent."* According to the same investigator, the roots of the turnip and cabbage continue to absorb water, even when the temperature of the soil is reduced very nearly to 0° Cent. (32° Fahr.). In the winter and early spring, when the temperature of the soil is low, the roots of trees and other perennials cannot absorb moisture unless they extend deep enough to reach the warmer strata beneath; under such circumstances, it not infrequently happens that if the air temperature rise high enough to allow evaporation, evergreen trees and shrubs are killed by too great loss of moisture.

243.—Evaporation or Transpiration. In aerial plants, when the temperature of the air is low, but little evaporation takes place from the leaves or other living organs, while an increase of temperature is followed by an increase in the rapidity of evaporation. It is probable that this is due (1st) to the closing of the stomata in the lower, and their opening in the higher temperature, and (2d) to the fact that in all ordinary cases, as the temperature of the air is lowered its degree of saturation is increased, and as its temperature is raised its degree of saturation is decreased. As transpiration appears to be a purely physical phenomenon, we scarcely need expect it to be as definitely or certainly affected by changes of temperature as are the proper functions of the plant.

244.—Assimilation. The lower limit of the temperature in which assimilation is possible varies much in different plants. The "Red-snow Plant" (*Protococcus*, sp.) of the Arctic regions grows rapidly upon the surface of the snow in a temperature which must be little, if any, above 0° Cent. (32° Fahr.); in the larch, assimilation takes place at from 0.5° to 2.5° Cent. (33° to 36° Fahr.), and in meadow-grasses at from 1.5° to 3.5° Cent. (35° to 38° Fahr.). In water-

* "Lehrbuch," English edition, p. 652.

plants the lower temperature limit is apparently somewhat higher than in aerial ones; thus in *Hottonia palustris* it is 2.7° Cent. (37° Fahr.); in *Vallisneria,* 6° Cent., or more (42° Fahr.); in *Potamogeton* from 10° to 15° Cent. (50° to 59° Fahr.).

Neither the maximum nor the optimum temperature has been determined for ordinary land plants; in *Hottonia palustris,* an aquatic plant, the maximum temperature for assimilation is, according to Sachs, between 50° and 56° Cent. (122° and 132° Fahr.).

245.—Metastasis. But little is accurately known as to the effect of an increase or decrease of temperature, within moderate ranges, upon those metastatic changes which take place in the ordinary growth of plants or the storing of reserve material. It is well known, however, that some plants live wholly in low temperatures, performing all their functions in air or water little, if any, above the freezing point. Thus in the "Red-snow Plant," above cited, the metastatic changes must take place very near 0° Cent.

In the polar waters, where the temperature is from 3° to 5° Cent. (37° to 41° Fahr.), or even less, myriads of diatoms flourish, and in seas but little warmer many of the higher sea-weeds (Fucaceæ and Florideæ) abound. In all these cases the metastatic changes (as well as all others) must take place at these low temperatures. In ordinary land-plants it is to be observed that whereas assimilation takes place only during the light part of the day, when it is warmer, metastasis takes place not only in daylight, but even more rapidly in darkness, when the temperature is considerably lower.*

Sachs measured the length of plumule developed upon different plants of the same species subjected to different temperatures, and in this way found the approximate optima for several species, as follows:†

---

* It must not be forgotten, however, that assimilation is dependent upon light, while metastasis is somewhat checked by it, and this is doubtless by far the most important relation; and still it is a significant fact that in ordinary land-plants metastasis continues when assimilation has stopped.

† In "Physiologische Untersuchungen über die Abhängigkeit der

Pea	26° Cent.	(78.8° Fahr.).
Wheat (winter var.)	34° "	(92.7° "
Indian corn	34° "	(92.7° "
Scarlet Bean	34° "	(92.7° "

In Sachs' and others' observations upon the growth of roots, it was found that the most rapid growth took place for different plants at the following temperatures :

Scarlet Bean	26° Cent.	(78.8° Fahr.).
Pea	26.6° "	(79.9° "
Flax	27.4° "	(81.3° "
Wheat (winter var.)	28.5° "	(83.3° "
Barley (summer var.)	28.5° "	(83.3° "
Indian corn	34° "	(92.7° "

In the deposit of reserve material there can be no doubt that metastasis often takes place at lower temperatures than assimilation ; thus the storing of starch in the potato tubers, and in many other subterranean stems and roots, takes place in the soil which, at the time, is much cooler than the air.

In the growth of many plants in early spring, at the expense of reserve material in the roots or stems, the metastatic changes often take place at quite low temperatures. Thus perennial and biennial rooted plants, as many grasses, thistles, parsnips, etc., begin to grow almost as soon as the snow has disappeared, and the flower buds of many perennials develop equally early—*e.g.*, the hazel, elm, maple, liverleaf (*Hepatica*), Mayflower, etc.

As regards the metastatic changes which take place in the germination of seeds, we have much more definite information. Sachs has determined the minimum, optimum, and maximum temperatures for the germination of the seeds of the following plants :*

	MINIMUM.	OPTIMUM.	MAXIMUM.
Ind. corn.	9.4° C.= (48.8° F.).	34° C. = (92.7° F.).	46° C. = (115.2° F.).
Scar. B'n..	9.4° C.= (48.8° F.).	34° C. = (92.7° F.).	46° C. = (115.2° F.).
Pumpkin.	14° C.= (56.7° F.).	34° C. = (92.7° F.).	46° C. = (115.2° F.).
Wheat...	5° C.= (41° F.).	29° C. = (83.7° F.).	42° C. = (108.5° F.).
Barley...	5° C.= (41° F.).	29° C. = (83.7° F.).	37° C. = (99.5° F.).

Keimung von der Temperature," in "Pringsheim's Jahrbücher für Wissenschaftliche Botanik," Vol. II., 1860, p. 354.

* "Physiologische Untersuchungen," etc., op. cit., p. 365.

According to several observers, the minima and optima for the germination of the seeds of the following plants are:

	MINIMUM.	OPTIMUM.
Lepidium sativum....	1.8° C. = (35° Fahr.).	27.4° C. = (81° Fahr.).
Flax..................	1.8° C. = (35° "	27.4° C. = (81° "
White Mustard.......	0.0° C. = (32° "	27.4° C. = (81° "
Pea...................	6.7° C. = (43° "	26.6° C. = (80° "
Pole Bean...........	....	31.5° " . = (88.7° "
Sunflower............	....	31.5° C. = (88.7° "
Hemp.................	....	31.5° C. = (88.7° "
Watermelon..........	....	37.5° C. = (99.5° "

246.—Death Caused by High Temperature. When the temperature rises above a certain point the death of the plant takes place. Those plants, or parts of plants, which contain the least water are capable of enduring higher temperatures than those which are more watery. Thus at from 65° to 80° Cent. (149° to 177° Fahr.) many dry spores and seeds are uninjured, while in water they are generally killed when the temperature exceeds 50° or 55° Cent. (122° or 131° Fahr.). For ordinary growing parts of plants the temperature must be, as a rule, considerably lower than those given above. Few aquatic plants can endure a prolonged temperature much, if any, above 40° Cent. (104° Fahr.), and at 50° Cent. (122° Fahr.) most terrestrial plants are soon killed. It appears, also, that at temperatures much lower than these some plants are killed; thus, according to Hofmeister,* the organization of the protoplasm of the plasmodium of *Didymium serpula* (one of the Slime Moulds) is destroyed by heating it, in air, to 35° Cent. (95° Fahr.), and in the nearly related *Fuligo varians* the same destruction follows at 39° Cent. (102° Fahr.).

The immediate cause of death appears to be the coagulation of the albuminoids of the protoplasm. The protoplasm thus loses its power of imbibing water, and the cells consequently lose their turgidity. In watery tissues chemical changes at once begin, resulting in the rapid disintegration

* "Die Lehre von der Pflanzenzelle," 1867, p. 27.

of the substances in the cells, accompanied by an evolution of carbon dioxide.

247.—Death Caused by Low Temperature. In many respects the results of too great a reduction of temperature are similar to those produced by too great an elevation. There is observed the same coagulation of the albuminoids, resulting in the destruction of the power of the protoplasm to imbibe water, and, as a consequence, in the loss of the turgidity of the cells. Moreover, as in the case of injury from high temperature, those cells which are the most watery are the ones which, other things being equal, are injured most quickly by a reduction of temperature. Embryo plants in seeds, when dry, are able to endure almost any degree of low temperature; but after they have germinated, and the cells have become watery, they are generally killed by a reduction to, or a few degrees below, 0° Cent. (32° Fahr.). So, too, the comparatively dry tissues of the winter buds and ripened stems of the native trees and shrubs in cold countries are rarely injured even in the severest winters, while the young leaves and shoots in the spring are often killed by slight frosts.

Death from low temperature is always accompanied by the formation of ice-crystals in the succulent tissues; these are formed from the water of the plant, which is abstracted from it in the process of congelation. Much of the water thus frozen is that which fills the cavities (vacuoles) of the cells, while some of it is that which moistens the protoplasm and cell-walls. Now it is evident that the water in the large vacuoles is much more easily congealed than that in the protoplasm and cell-walls; for in the latter the force of adhesion between the molecules of protoplasm or cellulose and the imbibed water offers a considerable resistance to the separation of the water in ice-crystals, and this resistance is greater as the contained water is less. As the liquid in the vacuoles is not pure water, but a mixture of several solutions, it freezes at a lower temperature than water, and then, according to a well-known law of physics, separates into pure ice-crystals and a denser unfrozen solution. By a greater reduction of temperature more ice-crystals may be separated out, and the

remaining solution made denser still. These adhesive forces tend to retard the formation of ice-crystals, and it is probable that it is only in extremely low temperatures, if at all, that the liquids in the plant are completely solidified.

248.—A plant which has been frozen may survive in many instances if thawed slowly, whereas if thawed quickly its vitality is generally destroyed. Thus many herbaceous plants will endure quite severe freezing if they are afterward covered so as to secure a slow rise of the temperature, and many bulbs, tubers, and roots will survive the severest winters if covered deeply enough to prevent sudden thawing. Likewise turgid tissues, which are not living, as those of many succulent fruits, are injured or not by freezing, according as the thawing has been rapid or slow. From these facts it may be inferred that the injury in freezing is primarily of a physical instead of a chemical nature, and that it is mainly the withdrawal of water from its physical union with the solids of the cell. According to this view, the difference between slow and rapid thawing is that in the former the slowly liquefying water is reabsorbed by the same solids from which it had been abstracted, while in the latter the large amount of water set free is imperfectly absorbed, forming solutions which are unstable and subject to subsequent fermentive changes. It is probable that to these fermentive changes is due the coagulation of the albuminoids and the rapid disorganization of the protoplasm which accompany injury from freezing.

While the sketch given above is doubtless true in a large number of cases, it appears that in many other cases death follows freezing whether the thawing be rapid or not; and this indicates that besides the immediate causes of death already indicated, there are others which are as yet unknown to us.

§ II. Light.

249.—General Relations. Directly or indirectly plant-life, as indeed all life, whether vegetable or animal, is dependent upon light. Parasites and saprophytes may grow

in complete darkness, but they do so at the expense of material which has been elaborated in light. So, too, some parts of many ordinary plants grow in total darkness, as roots, tubers, bulbs, etc., but these depend for their carbohydrates upon the aerial, chlorophyll-bearing parts which are in the light. As will be shown in the sequel, this dependence of all life upon light is due to its relation to chlorophyll in the processes of assimilation ; and while other functions than that of assimilation and other orgar s than those which contain chlorophyll are somewhat affected by the presence or absence of light, or its greater or less intensity, yet these latter are of comparatively little moment when compared with the former.

The absorption of water by the plant appears to be entirely independent of light, and in most plants it takes place in its entire absence. Likewise it is probable that light itself does not directly affect the rate of evaporation of water from the leaves of higher plants. As, however, the stomata are generally opened more widely in light than in darkness, evaporation may be promoted by it in some cases.

250.—Light and Assimilation. It is first of all to be observed that chlorophyll itself is dependent upon light. Those parts of plants (with rare exceptions) which grow in darkness are destitute of chlorophyll, and even parts which contain chlorophyll lose it when placed for some time in complete darkness. When such a colorless plant is brought into the light it soon becomes green from the formation of chlorophyll in its protoplasm.

The decomposition of carbon dioxide, and the consequent evolution of oxygen, only take place in the light. As the light decreases in intensity from a certain point the amount of assimilation decreases ; on the other hand, there is a decrease in assimilation as the intensity increases unduly, and beyond certain points in either direction assimilation ceases. Thus there are here, as in the case of temperature, a minimum, optimum, and maximum ; but we cannot define their limits as readily, for want of a proper instrument.

251.—Experiments have often been made upon plants when placed in rays of different refrangibility, and it has

been shown (1) that the assimilation is greater in the whole beam (white light) than in any one of its constituent rays, and (2) that the amount of assimilation varies greatly in the different rays.* When plants are grown in the different rays of the spectrum, and properly protected, so that each receives but one kind of light, the amount of assimilation in each case is about as follows, that for white light being 100 :

Red,	Orange,	Yellow,	Green,	Blue,	Indigo,	Violet,
9.5	23.5	37.3	14.	8.2	5.	2.5

The less refrangible rays are thus seen to be far more efficacious than the more refrangible ones, and in the yellow and orange rays, which are the brightest to the eye, the greatest amount of assimilation takes place. From these rays there is a decrease toward each end of the visible spectrum, and in the so-called heat rays and chemical rays, found respectively beyond the red on the one hand and the violet on the other, there is no assimilation whatever.

252.—Light and Metastasis. Many of the metastatic changes in the plant take place in complete darkness, such as those connected with the growth of roots and other subterranean organs. In trees and thick-barked shrubs the metastatic changes which occur in the stems are in total darkness, and even in many herbs the thick cortical tissues must cut off the greater part of the light from the active interior cells. On the other hand, in a great number of aquatic plants their translucency is so great that every internal change must be in bright light, and in a few terrestrial plants—as, for example, in *Impatiens Balsamina*—the cortical tissues permit most of the light to penetrate to the inner active cells. These facts indicate a marked indifference of the metastatic changes to light, as compared with those of assimilation.

This indifference is further illustrated in the growth of flowers in the dark, where, with few exceptions, they develop as perfectly as in the light. So the colorless parasites—*e.g.*, *Monotropa*, *Aphyllon*, *Corallorhiza*, etc.—and all the fungi

* The earliest experiments of much value were those of Charles Daubeny, "On the Action of Light upon Plants, and of Plants upon the Atmosphere," pub. in *Phil. Trans.*, 1836.

grow either in light or darkness. It must not be inferred, however, that there is a complete indifference to the presence or absence of light, for careful experiments show that light favors some metastatic changes, while in many cases it actually exerts a retarding influence. Thus if all other conditions, as temperature, moisture, etc., are made constant, the rapidity of growth of most aerial stems is considerably greater in darkness than in light; while under similar conditions the growth of the leaves of most plants is less. Experiments show that the retardation of growth is due to the rays of high refrangibility, blue, indigo, violet, and ultra violet, and that, so far as the metastatic changes under consideration are concerned, the less refrangible rays are equivalent to darkness.

§ III. Heliotropism.

253.—The retarding influence of light upon the growth of stems gives rise to a curvature when the illumination is stronger upon one side than upon the other. Thus, as is well known, most plants, when grown in windows, bend strongly toward the light, and if their position be afterward reversed they soon bend again toward the side of greatest illumination. To this phenomenon, which is an exceedingly common one throughout the vegetable kingdom, the name Heliotropism* has been given. The explanation which is commonly given is that the light retards the growth on the illuminated side, while the shaded side elongates, resulting in a tension which necessarily produces a curvature.

254.—Evidently allied in some way to heliotropism is the bending of certain organs *away from the light.* Thus the leafless stems (runners) of *Saxifraga sarmentosa,* when grown in a window so that they are illuminated upon one side more strongly than upon the other, curve toward the darker side. This opposite bending has been called Negative Heliotropism, and is supposed to be caused by light in some way not yet understood. The tendrils of the Vine and Virginia

---

*** From the Greek ἥλιος, the sun, and τρέπειν, to turn.**

Creeper (*Ampelopsis*) are negatively heliotropic, and they are thus enabled to reach and attach themselves to the surfaces—*e.g.*, walls, tree-trunks, etc.—which give them support. The same organ may be positively heliotropic in one stage of its growth and negatively so in another; thus the younger internodes of the ivy (*Hedera*) bend toward the light, and the older ones away from it; and the runners of *Saxifraga sarmentosa*, mentioned above, are positively heliotropic as soon as they develop tufts of leaves upon their free extremities.

The rays of light which cause the curvature are those having the greatest refrangibility. Sachs' experiment shows this conclusively; he grew plants in light which had passed, on the one hand, through a solution of potassium bichromate, and, on the other, through one of ammoniacal copper oxide; in the light passed through the first solution (red, orange, and yellow rays, and a portion of the green) there was no curvature whatever, while in the blue, indigo, and violet rays passed through the second solution the heliotropic curvature was strongly shown.

§ IV. Geotropism.

255.—Nearly all organs of plants have a definite, normal direction of growth, which is in general terms, either toward or away from the earth. Thus the plasmodium of *Fuligo varians* creeps upward; the conidia-bearing hyphæ of moulds grow upward, while the root-like hyphæ grow downward; the stems of many mosses grow upward, and their rhizoids downward; in the higher plants the stems, as a rule, grow upward, some root-stocks and other stems growing downward, however, while the roots, as a rule, grow downward. To these phenomena of growth the name Geotropism* has been given; when the direction of growth is downward, the organ is said to be positively geotropic, when upward, negatively geotropic.

Knight long ago proved gravitation to be the cause of

* From the Greek γῆ, γέα, the earth, and τρέπειν, to turn.

geotropism.* He placed germinating seeds upon wheels, which were made to rotate rapidly, in one series of experiments in a vertical, and in the other in a horizontal direction. In the first case he found that the roots grew directly away from the centre of the wheel, and the stems toward it—that is, having in his experiment substituted centrifugal force for gravitation, leaving all other conditions unchanged, he found that the root grew in the direction of that force, and the stem opposite to it. In the second series of experiments, in which gravitation and centrifugal force were made to act at right angles to each other upon the growing plantlets, the direction of growth coincided with that of the diagonal of the two forces, the roots growing diagonally outward and downward, the stems inward and upward. Dutrochet afterward showed, by similar experiments, that many leaves are geotropic, turning their under surfaces toward the circumference, and their upper toward the centre of the wheel.†

256.—If positively and negatively geotropic organs are placed in what may be termed their normal positions, they grow on the one hand downward and on the other upward, without any curvature, and in such case the cells in all parts of any section of either the ascending or descending portions show a symmetrical development. But if such symmetrically developed positively and negatively geotropic organs are afterward placed in a reversed or horizontal position, they will become considerably curved in order to assume their normal positions. Thus the first roots of most young plants, if placed horizontally, soon become curved downward near their tips; this takes place even when there is considerable resistance to the curvature, as is shown by the penetration of roots into mercury. A similar curvature in an upward direction, however, takes place in most stems when placed horizontally; in grasses the curvature is almost entirely confined to the nodes. In such curved parts of roots and stems the cells are more elongated upon the convex than upon

---

* "On the Direction of the Radicle and Plumule during the Vegetation of Seeds." *Philosophical Transactions*, 1806.

† "Memoires," Paris, 1837.

the concave side, and it is evident that this is the immediate cause of the bending. We do not, however, know how gravitation causes this inequality in the growth of the cells, and the problem is the more difficult from the fact that the more rapid elongation of the cells is in one case upon the upper and in the other upon the under side of the organ. Moreover, in "weeping trees" the branches are positively, instead of negatively, geotropic, although we know of no structural difference between these and the branches of ordinary trees.

§ V. CERTAIN MOVEMENTS OF PLANTS.

257.—Under this head are to be considered a few only of the more important movements in plants. It must be remembered that living protoplasm has everywhere, under proper conditions, the power of spontaneous movement. In the lower forms of vegetation this results in visible movements, which are of common occurrence; but in the greater part of the vegetable kingdom, while the protoplasm is doubtless as active, the cell-walls which enclose it are so rigid that its physical activity is incapable of producing external movement. Thus most parts of ordinary plants do not perform movements which are the direct results of the physical activity of the protoplasm; but this is not because of a want of activity in the protoplasm, but mainly from the rigidity of the walls surrounding it. In a comparatively small number of instances, however, the structure of the organs of even the higher plants is such that movements directly due to protoplasmic activity are performed. Such are the so-called spontaneous movements of the leaves of some plants, and those dependent upon external stimuli, as light, heat, mechanical irritation, etc., which have been called paratonic movements.

258.—Spontaneous Movements. The most remarkable case of movements apparently not dependent upon external agents is that of the leaves of *Desmodium gyrans*, an Indian plant. The small lateral leaflets of the trifoliate leaf bend upon their slender stalks (petiolules) in such a way that their

apices describe nearly a circle. A revolution occupies from two to five minutes if the temperature is above 22° Cent. (72° Fahr.). This continues, when the conditions are otherwise favorable, in darkness as well as in the light. Other less noticeable movements of this nature occur in many plants—*e.g.*, Clover, Mimosa, Oxalis—but they are often hidden by the more marked movements due to other causes. The active portion of the moving organ (in the cases cited above, a portion of the leaf-stalk) consists of a tissue composed of thin-walled cells, forming, in many cases, a thickened "pulvinus." The cells are turgid and the tissues are in a state of tension. When movements occur, it appears that the protoplasm in certain layers of cells permits the escape into the intercellular spaces of a portion of the water of the vacuoles; it is, however, quickly absorbed again and the cells rendered thereby turgid, while the escape of water takes place in contiguous layers, to be quickly absorbed again, and so on regularly around the axis of the contracting organ.

259.—Movements Dependent upon External Stimuli. These are exhibited by many parts of the higher plants—*e.g.*, leaves in Mimosa (the Sensitive Plant), Cassia, Clover, Oxalis, Dionæa, etc., stamens of many Compositæ, of Barberry, Portulaca, etc., stigmas of Martynia, Mimulus, etc. In the Sensitive Plant, the leaves, when touched roughly or jarred, close up quickly by the secondary leaflets moving upward and forward, so that the upper surfaces of the pairs are approximated to each other; next, the primary leaflets bend downward, and at the same time approach each other, and finally the whole leaf bends downward. The movements are in all cases at the bases of the organs, where tissues are developed similar to those in the spontaneously moving organs (paragraph 258). In the other cases essentially the same movements and mechanism are found. When the movements occur, there is an escape of the water of the vacuoles from the cells in one side of the organ, and this side is, as a consequence, shortened and made concave. After a time the water is reabsorbed and the organ resumes its normal position. In addition to the mechanical stimuli of jarring, concussion, etc., greater or less amounts of light,

increase or decrease of temperature, and electrical discharges, may cause movements. Those movements which are brought about by changes in the amount of light constitute what are known as the "sleep" and "waking" of plants. Thus the leaves of the Sensitive Plant close up in darkness exactly as from a concussion, but they remain closed until the reappearance of the light.

260.—The power of movement, whether spontaneous or paratonic, may be temporarily suspended by certain external conditions. Thus, according to Sachs, transitory rigidity or immobility takes place under the following conditions:

1. *Low Temperature.* In *Mimosa pudica* rigidity commences at about 15° Cent. (59° Fahr.), in *Desmodium gyrans* at about 22° Cent. (72° Fahr.).

2. *High Temperature.* Mimosa slowly becomes rigid at 40° Cent. (104° Fahr.), and very quickly at 50° Cent. (122° Fahr.).

3. *Darkness.* Long exposure to darkness (twenty-four hours or more) produces a rigidity which is only removed by a long exposure to light.

4. *Insufficient Moisture.* When the supply of water to the roots of the Sensitive Plant is too little, a partial, and sometimes almost complete, immobility is produced, which is soon removed, however, by copious watering.

5. *Insufficient Supply of Oxygen.* In a vacuum, or in an atmosphere of nitrogen, hydrogen, ammoniacal gas, etc., motile organs become immobile. On the other hand, in pure oxygen rigidity takes place also.

6. *Anæsthetics.* In the vapor of ether or chloroform the leaves of the Sensitive Plant become immobile, but in the air they soon regain their motility.

Mr. Darwin's experiments* upon the leaves of Drosera and Dionæa are confirmatory of the foregoing statements. The sensitive tentacles of the former and leaf-blades of the latter were rendered insensible to the peculiar stimulus of contact with soluble nitrogenous bodies when subjected to most of the above-mentioned conditions.

* "Insectivorous Plants." London, 1875. Chap. IV., IX., and XIII.

These facts indicate the correctness of the view that the movements are the results of the motility of the protoplasm.

261.—Movements of Nutation. In the organs of many plants an inequality of growth is often noticeable, one side growing for a time more rapidly than the other. If this is followed by a more rapid growth upon the other side, and this again by a more rapid growth upon the first side, and so on, alternating from side to side, simple movements of nutation will take place, the apex of the organ swaying or oscillating from side to side in one plane. If the tracts of unequal growth pass slowly and regularly around the organ, its apex will describe a circle in its nutation.

Of simple nutation in one plane many leaves afford good examples; thus in the bud the growth is greatest upon the outer or under side of each leaf, which, as a consequence, is bent upward, but in the opening of the bud the greater growth takes place upon the upper side. The greater growth of the upper side of an organ has been termed *epinasty*; that of the lower side, *hyponasty*. Many floral leaves exhibit first hyponasty and afterward epinasty, the first in the bud and the second in anthesis (*i.e.*, the opening of the flower). Many stamens and styles exhibit nutations of this nature; thus in Claytonia both sets of organs are at first erect, but afterward they become divergent by epinasty.

In many cases, particularly in leaves and the parts of flowers, these movements of nutation are controlled by various external agents, among which light and heat are the most important. To these are to be referred the successive opening and closing of many flowers, and the diurnal and nocturnal positions of the leaves of many plants.

262.—Of the second class of nutations, the leaves of the onion, and the ends of the stems and the tendrils of climbing plants, furnish good examples. These rotate through circles or spirals, in the case of the hop and honeysuckle to the left, and in the bean and morning-glory to the right.*

---

* To the right, or from left to right, is opposite to the direction of the hands of a watch; to the left, or from right to left, is in the direction of the hands of a watch.

When such rotating stems come in contact with an upright object they continue their rotation, and in this way come to twine around it. The plants mentioned above afford common examples of twining. In the case of tendrils nutations also occur; but after coming in contact with any object there is a very unequal growth of the two sides, that in contact with the object growing very slowly, as compared with the rapidity of growth of the outer side. Thus De Vries found that in the tendrils of the pumpkin twined around an object 1.2 mm. in diameter the ratio of the growth of the inner side to that of the outer was as 1 to 14. This inequality of growth is due to a retardation of growth upon the inner side and an acceleration upon the outer. In some cases there appears to be an actual contraction of the inner side.

263.—Movements of Torsion. In many cases in the higher plants the stems or other organs become twisted upon their axes. Even in the lower plants this is not uncommon—*e.g.*, in *Nitella,* the pedicels of mosses, etc. This twisting appears in many cases to be due to a peculiar inequality in the growth of the tissues. Thus if the outer layers of cells grow in length more rapidly than the inner ones, the stem will become twisted upon its axis, and the greater the inequality in growth of the inner and outer layers, the greater the torsion. In some cases torsion arises in a much simpler way, by the twisting due to the unequal distribution of the weight of certain organs, as in some prostrate plants, where the weight of the leaves and the advancing and obliquely ascending growing extremity of the stem produce torsions which become permanent by the hardening of the tissues. Likewise torsions may arise on account of the heliotropism or geotropism of an organ itself, or of organs connected with it.

It may be in place here to direct attention to the fact that inequalities in the growth of the tissues of plants are of common occurrence. They are, however, for the most part of such a nature as to prevent torsions of the stem, giving it, on the contrary, a rigidity which enables it to stand erect. If the pith of a growing stem of a Dicotyledon be isolated from the surrounding tissues, the former elongates, while the latter contracts, showing that the pith has grown more rapidly in

length than the other tissues. Thus in a young internode of the Mountain Ash, 60 mm. long, the pith, when isolated, elongated 3 mm., while the surrounding parts shortened 1 mm. Close examination of the tissues surrounding the pith shows that they also have developed unequally. Sachs expresses this inequality by the formula, $E < C < X < P$, which indicates that the epidermis is shorter than the cortex, the cortex shorter than the xylem, and the xylem shorter than the pith. It is at once evident that in such a condition of things the epidermis is elongated by the other tissues; the cortex is shortened, on the one hand, by the epidermis, and elongated on the other by the xylem and pith; the xylem is shortened by the cortex and epidermis, and elongated by the pith; while the pith is shortened by the three surrounding tissues. There is thus a considerable tension in the several tissues, and upon this condition it may be remarked:

1st. That it produces a rigidity of the stems or other organs in which it occurs.

2d. That it tends to prevent ordinary torsion; for the twisting of such a stem must elongate still more the already elongated tissues, while contracting the shortened ones; on the other hand, there is some tendency to an internal torsion.

3d. That the exact length of a stem is dependent upon a balancing of the tensions of its tissues.

There are in many cases tensions whose directions lie at right angles to the foregoing. Thus in the trees of the colder climates the growth of new tissues from the cambium layer produces an outward pressure upon the bark, and an equal inward pressure upon the wood. Even in herbaceous plants similar tensions are often to be observed, the epidermis being laterally distended by the enclosed tissues. Tensions in this direction have been denominated transverse tensions, to distinguish them from the others, which may be called longitudinal tensions.*

---

* For a full discussion of tensions the student is referred to larger works, such as Sachs' "Lehrbuch," and his "Experimental-Physiologie."

The whole subject of the movements of plants, including heliotropism and geotropism, is fully treated by Mr. Darwin in his recent work "The Power of Movement in Plants," New York, 1881.

PART II.

SPECIAL ANATOMY AND PHYSIOLOGY OF PLANTS, AND OUTLINES OF THEIR CLASSIFICATION.

CHAPTER XIII.

CLASSIFICATION.

264.—In order to obtain a definite knowledge of the comparative structure of plants, it is necessary here to take up in order the different groups, and to study with some care the more important modifications and differences noticeable in the plant-body. This study, so taken up, is intimately connected with the classification of plants; the differences and modifications of structure which we study in order to gain a better knowledge of plants as a whole, are the very ones which serve to separate the vegetable kingdom into larger or smaller groups. This part (Part II.) of this treatise will, therefore, include the outlines of the Classification of Plants, as well as a discussion of Special Morphology.

265.—(1.) In the classification of living objects they "are arranged according to the totality of their morphological resemblances, and the features which are taken as the marks of groups are those which have been ascertained by observation to be the indications of many likenesses or unlikenesses."* Such an arrangement is "a statement of the marks of similarity of organization, and of the kinds of structure which, as a matter of experience, are universally found associated together."

---

* T. H. Huxley in the article "Biology," in "Encyclopædia Britannica," ninth edition, Vol. III., p. 683.

266.—(2.) Every natural classification takes into consideration not only the adult characters, but also those of the embryonic life of its objects. It is not enough to know the differences and resemblances between two plants in their adult state ; we must also know whether they differed or not in their modes of reaching that state. In other words, in order to determine the degree of relationship existing between two or more plants, *all* the characters of each plant, as presented in its whole life, must be taken into the account. By ignoring this important law great confusion has arisen, especially in the lower groups of plants.

267.—(3.) There is still another factor which should enter into classification. Every classification should show real relationship, not similarity alone ; it should bring together not those which simply show present coincidences, but those in which similarity of form indicates similarity of origin ; in addition to structural relationship, it should show genetic relationship. This can be accomplished only by a study of the genealogy of plants, a subject surrounded by many difficulties. In but few cases can we trace an ancestral line, and yet it is desirable that we should use the facts we have, as by so doing we shall be the more likely to discover others.

(*a*) It is a mistaken notion that living things can be grouped naturally by taking into consideration only one, or even two or three characters. Botany and zoology are full of the *dêbris* of attempts at classifications upon single characters, and in every case such classifications have proved a hindrance to knowledge. The division of the vegetable kingdom into Flowering and Flowerless Plants, by Ray,* in 1703, is an illustration of one based upon a single character. The influence of this classification, which is even yet much followed, has been injurious. It has kept alive the notion that the so-called Flowerless plants are quite different as to their reproductive organs from the Flowering ones ; it fixed an imaginary gulf between groups of plants, some at least of which are in nature placed side by side. Endlicher's† two great groups, Cormophyta and Thallophyta, are likewise based upon a single character, and are, as a consequence, misleading. The Thallophytes are

* John Ray : "Methodus Plantarum emendata et aucta."

† Stephen Endlicher : "Genera Plantarum secundum Ordines Naturales disposita." 1836–40.

not all thallus plants, nor are all the thallus plants found in the Thallophyta; on the other hand, the Cormophytes are not all plants with trunks or stems.

(*b*) We often, however, retain in our present classification some of the groups founded originally in this erroneous way, and even sometimes retain their old names. For example, the group Phanerogamia includes now the same plants it did when its exceedingly inapplicable name (Phanerogamia, from φανερός, open to sight, and γάμος, marriage) was applied to it; but it now rests upon a more scientific basis. The name is now unmeaning, and refers to no character or set of characters now used to designate the group; and, more than this, its etymological signification is actually directly opposite to the facts as now known. The term Cryptogamia (κρυπτός, hidden, and γάμος, marriage) no longer exists in a scientific sense, as it is no longer the name of a group of plants; not only has the term now no meaning (for the plants it refers to have a fertilization which is far less "hidden" than in the so-called Phanerogams), but the plants it formerly designated by a negative character are now known by positive characters to belong to several groups. We may still use the word Cryptogam in speaking of the members of certain groups of plants, just as in zoology we frequently make use of the word Invertebrate; but in neither case are the terms the names of natural groups, or of natural assemblages of groups. It is convenient to retain them as popular names of certain artificial assemblages of groups.

(*c*) The term Thallophyta is to be placed in the same category. It is still used to designate a great assemblage of the lower plants, but the original meaning of the term is lost, and the limits of the group to which it was applied have been somewhat changed, while the plants composing it have undergone an entirely new distribution into new groups. Nevertheless, it is convenient to retain the term, although in this, as in the previous cases, care must be taken not to suppose that when used it designates more than an artificial assemblage of natural groups of plants.

(*d*) The importance of the study of the individual development of plants can hardly be overestimated. What Embryology has done for zoological, it doubtless can do for botanical classification. It is already bearing fruit; the recent advances in the classification of the algæ and fungi are due to a study of the whole life of the individual. In the fungi the long list of spurious families and genera, and the yet longer one of spurious species, bear witness against the system of classification under which they came into existence.

(*e*) There is another reason for studying closely the life-history of the individual, which is that it throws some light upon the difficult questions relating to the ancestry of plants. The life-history of the individual appears to bear much resemblance to the life-history of the species; and while no doubt it would be unsafe in any particular case

to assume that the specific development had followed lines parallel to those of the individual, yet the latter may always serve to point out the probable course of the former.

268.—Applying the preceding principles, so far as possible, we find that the vegetable kingdom may be quite readily separated into six principal Divisions, which, although by no means distinct, are capable of being quite clearly characterized. To these must be added a seventh, composed mainly of unclassified and poorly understood forms. These seven Divisions, beginning with the lowest, are, (1) Protophyta, (2) Zygophyta, (3) Oophyta, (4) Carpophyta, (5) Bryophyta, (6) Pteridophyta, (7) Phanerogamia, or Anthophyta.

Their relation to the old groups Cryptogamia, Thallophyta, etc., may be seen from the following tabular comparison :

I. Ray, 1703; Linnæus, 1735.	II. De Candolle, 1813.	III. Endlicher, 1836–40.	IV.
Flowerless (Ray), Cryptogamia (Linnæus).	....	....	1. Protophyta.
	Cellular Plants.	Thallophyta.	2. Zygophyta.
			3. Oophyta.
		....	4. Carpophyta.
	....	....	5. Bryophyta.
Flowering (Ray), Phanerogamia (Linn.)	Vascular Plants.	Cormophyta.	6. Pteridophyta.
		....	7. Phanerogamia.

The arrangement in the fourth column, which will be followed in this book, is essentially that of Sachs, with some modifications, which will be pointed out hereafter.

It is only necessary in this place to say that the classification here given does not recognize the old groups *Algæ* and *Fungi*. The terms are, however, quite useful, if properly used and understood, and consequently they will be retained when general reference is made to the chlorophyll-bearing and the chlorophyll-free Thallophytes. By the term alga must be understood a Thallophyte which contains chlorophyll; and by fungus one which is saprophytic or parasitic in habit, and which is, as a consequence, destitute of chlorophyll. The terms have thus, as here used, a physiological meaning only, and not a classificatory one.

CHAPTER XIV.

THE PROTOPHYTA.

269.—The Protophytes are the lowest and simplest plants. In many cases they are exceedingly minute, requiring the highest powers of the microscope for their study. For the most part the cells are poorly developed; the protoplasm is frequently destitute of granular contents; the nucleus is wanting in many cases, and not infrequently there is either no cell-wall, or only a poorly developed one. The cells in all cases have little or no coherence, and even when they are united into loose masses, each cell retains nearly as much independence as in the unicellular forms. The differentiation of cell-form is very slight, even in those cases where there is the greatest coherence of cells, and yet in some orders certain cells of the filaments are uniformly larger than the others, as the "heterocysts" of *Nostoc*, and the "basal cells" of the filaments of *Rivularia*.

270.—No sexual organs are known, and whether the sexual act occurs or not is somewhat doubtful. As, however, we must not expect to find well-developed organs or as distinct a sexual act in these simple organisms as in more complex ones, it is possible that both exist in the group, but have hitherto been overlooked or misunderstood.

Their most common mode of reproduction is by fission, and in only a few cases by internal cell-division.

271.—The lowest Protophytes are destitute of chlorophyll, or any other coloring-matter, and in those orders in which chlorophyll occurs it is usually associated with a blue or red pigment. algae

Many Protophytes exist in masses of a considerable size, composed of large numbers of individuals imbedded in a

gelatinous matter, which appears to be formed by a partial degradation of the walls of the cells. They are mostly aquatic ; and the species which are terrestrial live in damp and generally shaded places.

§ I. Class Myxomycetes. The Slime Moulds.

272.—In this class is included a large group of remarkable organisms, which differ in many respects from all other vegetable structures. In many of their characters, as in having no cell-wall during the period of their active growth, in being destitute of a nucleus, in their mode of nutrition, and in the motility of their naked protoplasm, they resemble certain Monera among the Protozoa ;* while, on the other hand, they have a close external resemblance to certain higher fungi (puff-balls and their allies).

273.—It is difficult to give the Myxomycetes a satisfactory place in a system of classification. They have no structural affinities with plants higher than they are, nor with any lower ; they stand alone, and appear to belong to a different genetic line. So, although taken up here, they must not be regarded as on that account the lowest or the first of the Protophytes.

274.—All members of this class agree in being composed during the vegetative portion of their existence of naked masses of protoplasm (Fig. 140), which are yellow, brown, purple, etc., but never green. These *plasmodia,* as they are called, are, during the period of their active growth, endowed

* There are fewer reasons now than formerly against regarding these as near relatives of the Monera. We no longer imagine an absolute line of separation between the lower portions of the great domain of life, and hence may now admit relationships which formerly were inadmissible. It is by no means an improbable hypothesis that in the Myxomycetes we have the *terrestrial phase* and in the Monera the *aquatic phase* of a common group of organisms. The Myxomycetes are not Monera, but they are Moneran in their structure, and probably also in their affinities. All the differences between the Myxomycetes and a Moner like *Protomyxa,* for example, are probably referable to the terrestrial habit of the former as contrasted with the aquatic habit of the latter.

with a remarkable motility, enabling them not only to change their form, but their place also. When the protoplasm passes into a condition of rest, it forms itself into small rounded masses, each of which secretes a covering of cellulose about itself. This resting condition may be brought about in two ways: first, through unfavorable conditions, as the absence of the requisite amount of moisture; in such

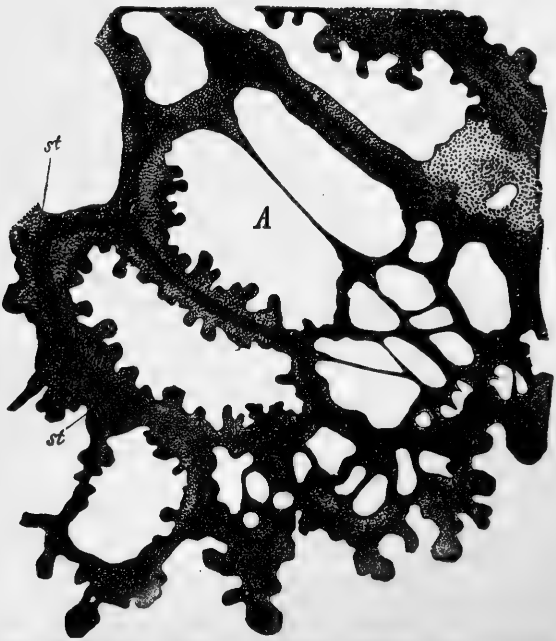


Fig. 140.—Plasmodium of *Physarum leucopus* (*Didymium leucopus* of Link). *st*, the more granular central part of the threads. × 350.—After Sachs.

case the masses formed are larger, and irregular in size, and constitute the so-called *sclerotium* stage; upon the return of the proper conditions the sclerotia return to the soft and motile condition of the original plasmodium; the second mode of formation of the resting stage takes place only when the plasmodium has apparently concluded its period of vegetation; the protoplasm becomes heaped up in a compact or even elevated mass, which then separates internally

into a large number of minute rounded bodies, the spores, each of which is provided with a cell-wall. This latter is called the spore-bearing stage, or simply the fructification of the organisms.

275.—When placed under proper conditions of moisture

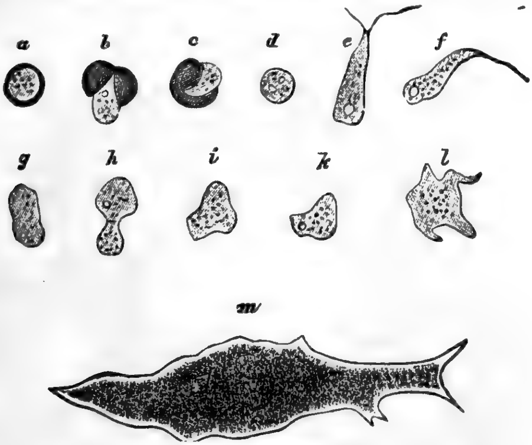


Fig. 141.—*Fuligo varians* (*Æthalium septicum* of Fr.). *a* spore; *b*, *c*, spore-case rupturing and permitting the protoplasmic contents to escape; *d*, rounded mass of naked protoplasm escaped from the spore-case; *e*, *f*, ciliated swarm-spore or zoospore stage; *g*, *h*, *i*, *k*, *l*, amœba stage; *m*, young plasmodium.—After Prantl.

and temperature, the spores burst their walls, and the imprisoned protoplasm in each escapes and soon becomes a motile, nucleated mass, provided with a cilium, or having an amœboid form; in this stage (called the swarm-spore) it repeatedly divides by simple fission (Fig. 142). After a day or two, the swarm-spores, now destitute of cilia, begin the reverse process of coalescing, two or more of them fusing into a common mass; the process may continue until a new plasmodium is formed, differing from the first one mentioned only in size (Fig. 141, *a* to *m*, and Fig. 143). (See Note on page 49.)

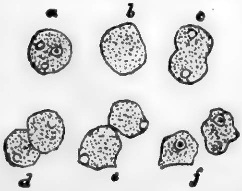


Fig. 142.—Swarm-spores of *Chondrioderma difforme* (*Didymium Libertianum* of De Bary) undergoing fission. × 390.—After De Bary.

276.—The classification of the Myxomycetes is mainly based upon the fructification, which usually consists of a

sporangium, which may be distinct (Fig. 144, *B*), or it may be a flattish, cake-like mass, the so-called *æthalium*, directly derived from the plasmodium. In most cases the spore-bearing masses contain internally, besides the spores, a structure called the *Capillitium*, consisting of thin-walled, spirally thickened, or otherwise marked tubes variously disposed (Fig. 144, *C, cp*). In some cases, where there is a distinct sporangium, the pedicel of the latter is continued into it as a central column; this is known as the *Columella;* it may send out branches which support the walls of the sporangium.

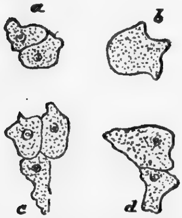


Fig. 143. — Swarm-spores of *Chondrioderma difforme* (*Didymium Libertianum* of De Bary) coalescing or conjugating. × 390.— After Cienkowski.

(*a*) The following classification of the Myxomycetes is by Rostafinski.* He distinguishes seven orders:

Order I. Protodermeæ. Sporangia simple, of regular shape, not possessed of a capillitium, with violet spores.

Order II. Calcareæ. Sporangia simple or compound, often provided with a columella, spores violet or violet brown; whole fructification, with more or less deposits of carbonate of lime.

This includes many common species, under the genera *Physarum, Fuligo, Didymium, Spumaria,* etc.

Order III. Amaurochæteæ. Single sporangium or æthalium, without lime; spores, capillitium, and columella almost always uniformly black, or brownish-violet colored.

In this order the genus *Stemonitis* furnishes the most common species.

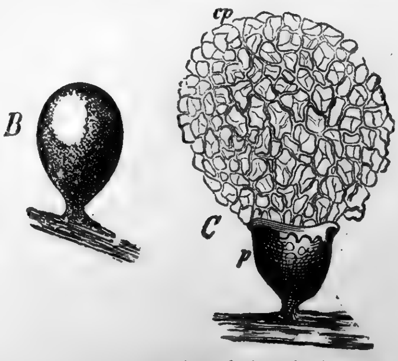


Fig. 144.—Fructification of *Arcyria incarnata* (*A. adnata* of Rtfki.). *B*, young sporangium; *C*, mature sporangium ruptured; *c p*, capillitium; *p*, wall of sporangium. × 20.—After Sachs.

Order IV. Anemeæ. Sporangium or æthalium without capillitium or lime; columella not evident, wall of sporan-

* "Sluzowce Monografia" by Joseph Rostafinski, 1875. Zopf ("Die Pilzthiere," 1884) extended the class so as to include many genera, e.g., Vampyrella, Protomonas, Protomyxa, Plasmodiophora, etc., which

gium without net-like thickenings, now and then symmetrically perforated.

Licea and *Tubulina* are genera of this order of which we have species.

Order V. Heterodermeæ. Sporangia without capillitium, columella, or lime; wall of sporangium delicate, when mature at least partly cracked, exposing the net-like flat thickenings of the inner side of wall; spores and thickenings of the inner wall in one and the same sporangium usually of uniform color.

Dictydium and *Cribraria* are our common genera.

Order VI. Columelliferæ. Spores, capillitium, and columella uniformly bright-colored, without lime; capillitium of very thin-sided tubes, without thickenings, combined into a thickly intricate but loose-hanging net.

Represented by the genus *Reticularia.*

Order VII. Calonemeæ. Walls of sporangia, spores, and capillitium usually uniformly colored in the same sporangium. Color variable from yellow to brownish or chestnut; more rarely olive green or grayish white; capillitium usually strongly developed; threads simple, or combined into a net, either entirely free or grown to certain places of the wall of the sporangium; walls of the threads very rarely smooth, usually provided externally with protruding thickenings, either spiral-shaped or under the form of numerous spines, warts, or transverse rings; without fixed columella; exceptionally containing lime, exclusively on the walls of the sporangia; now and then æthalia covered with a stout double cortex of colored cells.

Arcyria and *Trichia* are our common genera.

(*b*) Specimens of the Slime Moulds may be obtained for study by examining the surfaces of decayed logs, and the bark-covered ground in tan-yards. They may frequently be found on decaying leaves, and occasionally on the grass and mosses near decaying vegetable matter.

§ II. Class Schizomycetes.

277.—These are minute unicellular Protophytes, which reproduce mainly by transverse fission. The cells are generally somewhat elongated, often much so, although in one family they are spherical; they are sometimes provided with cilia, by means of which they move rapidly through the

---

are commonly placed in the Animal Kingdom. Zopf's system is followed by Berlese in Saccardo's "Sylloge Fungorum," vol. vii., 1888, in which all the known species in the world (about 450) are described.

water. They occur in solutions of organic matter in immense numbers, and are said even to appear in solutions of inorganic salts under proper conditions.*

278.—Order Bacteriaceæ. This includes the organisms known as Bacteria, and which are present in fermenting and putrefying matter; they also occur in the blood and the air-passages of diseased animals, and the tissues of some diseased plants, where they have been shown to be the cause of many kinds of disease. Cohn † defined Bacteria as "chlorophyll-less cells of spherical, oblong, or cylindrical form, sometimes twisted or bent, which multiply themselves exclusively by transverse division, and occur either isolated or in cell-families." Many forms have since been shown to produce spores, and these are most important agents in their multiplication and reproduction. In the unicellular Bacteria the cells resulting from division separate at once, while in the filamentous forms they remain in connection, forming elongated strings or threads. Bacteria sometimes form a jelly-like mass by the swelling up of their cell membranes; this is the *Zooglœa* stage. When they have exhausted the nutriment from the liquid, they form a pulverulent precipitate, which may be regarded as a *resting state.* "Most Bacteria present a motile and a motionless condition; the former is connected with the presence of oxygen."

It is now known that many Bacteria pass through various stages, e.g., *Coccus, Bacillus, Vibrio,* etc., which were for a time supposed to be generic forms, under which species were described, as was done by Cohn. The real limits of genera and species cannot in the present state of our knowledge of these organisms be determined. We may, for the present, make use of Cohn's system, remembering that it is merely a classification of observed forms.

* See Bastian's "Beginnings of Life," Vol. II., Appendix.

† "Researches on Bacteria" (Untersuch. über Bacterien) in "Beiträge zur Biologie der Pflanzen," Breslau, 1872. See a résumé of this paper in *Quarterly Journal of Microscopical Science,* 1873, p. 156. See also English accounts of further researches by Cohn, 1875, 1876; in the journal just cited, 1876, p. 259, and 1877, p. 81. Consult "The Bacteria," by Dr. A. Magnin; translated by Dr. Sternberg. Boston, 1880.

(*a*) Cohn separated Bacteria into four tribes, as follows:

(1) *Sphærobacteria*, with spherical cells. The only genus is *Micrococcus*. The species *M. crepusculum*, *M. candidus*, and *M. ureæ* produce certain kinds of fermentation; the color-producing species are *M. prodigiosus* (*a*, Fig. 145), which causes the blood-like patches on bread, flour, paste, etc., *M. luteus*, *M. aurantiacus*, *M. chlorinus*, *M. cyaneus*, and *M. violaceus*; those producing or accompanying diseases are *M. vaccinæ*, *M. diphthericus*, *M. septicus*, and *M. bombycis*. This latter group is of great importance, but it is one the investigation of which presents unusual difficulties. Other species than those named are supposed to exist.

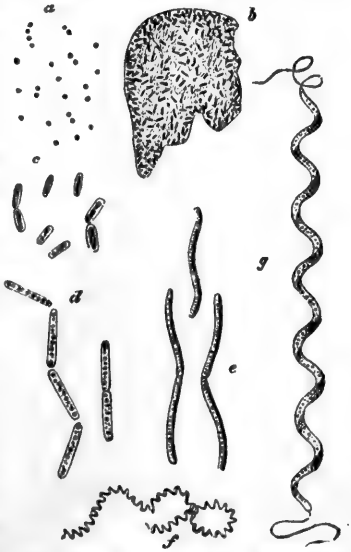


Fig. 145. *a*, *Micrococcus prodigiosus*, (*Monas prodigiosus* of Ehrenberg); *b*, *Bacterium Termo*, zooglœa stage; *c*, *Bacterium lineola*; *d*, *Bacillus ulna*; *e*, *Vibrio Rugula*; *f*, *Spirochæte plicatilis*; *g*, *Spirillum volutans*. × 650.—After Cohn.

(2) *Microbacteria*, with very small cylindrical cells. The only genus is *Bacterium*. The species are, *B. Termo* (*b*, Fig. 145), the common agent of putrefaction; *B. lineola* (*c*, Fig. 145), a larger species found in brooks and ponds; *B. xanthinum* and *B. syncyanum*, which are color-producing; and *B. æruginosum*, which is found in blue-green pus.

(3) *Desmobacteria*, with filiform cells. There are two genera, *Bacillus*, with the filament straight, and *Vibrio*, with the filament curved or undulated. Of the first there are three species, viz.: *B. subtilis*, which is the butyric ferment; *B. ulna* (*d*, Fig. 145), much like the preceding, but larger; and *B. anthracis*, which is the cause or accompaniment of the diseases known as *anthrax* and "malignant pustule." *Vibrio* has two species, viz.: *V. Rugula* (*e*, Fig. 145), whose cells are thick and rather short; and *V. serpens*, whose cells are of smaller diameter, but of greater length than the preceding.

(4) *Spirobacteria*, with spirally twisted cells. There are two genera, *Spirochæte*, with a much twisted spiral; and *Spirillum*, with a less twisted spiral. Of the first the single species is *Sp. plicatilis* (*f*, Fig. 145), and of the second, *Sp. tenue*, *Sp. andula* and *Sp. volutans* (*g*, Fig. 145), the latter a gigantic species, with a flagellum at each end of the spiral.

(*b*) Bacteria may be readily procured for study by infusing a pinch

of cut hay or any other similar vegetable substance in warm water for an hour, and then filtering; the filtrate will, if kept at the ordinary temperature of a room (20° C.), and allowed free access of air, become turbid with Bacteria in the course of one or two days.

(*c*) By adding a drop of the hay infusion to Pasteur's solution,* made without sugar, the previously clear liquid is soon made turbid by the rapid increase of Bacteria.†

279.—Allied to the *Schizomycetes* are the species of *Saccharomyces* which produce fermentation in sugar solutions. The type of the genus is *Saccharomyces cerevisiæ,* the yeast plant (Fig. 146). It presents two conditions: in the first it is in the form of transparent round or oval cells, averaging .008 mm. (.0003 inch) in diameter; these reproduce by budding (a modification of fission), a small daughter-cell being formed by the side of the mother-cell, and sooner or later separating from it (Fig. 146, *a*, *b*). The other form consists of larger cells, which, by a division of their protoplasm, form four new cells within the parent-cell (Fig. 146, *c*, *d*). This is probably no more than the ordinary process of internal cell-division, although it has been thought to be of greater importance.‡ This formation of new cells by internal cell-division appears to occur only when the supply of nourishment is less abundant, as when the yeast is grown on cut slices of potato or carrot.

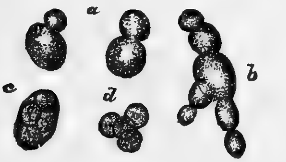


Fig. 146.—The Yeast Plant, *Saccharomyces cerevisiæ*. *a*, rounded cells from "bottom yeast," 50 hours after sowing in beer-wort; *b*, row of oval cells from "top yeast;" *c*, "bottom yeast" after cultivation on a piece of carrot, four cells forming in the interior of the parent cell; *d*, the four daughter-cells. *a* and *b* × 400, *c* and *d* × 750.—After Reess.

---

* Made as follows: Potassium phosphate, 20 parts; calcium phosphate, 2 parts; magnesium sulphate, 2 parts; ammonium tartrate, 100 parts; cane sugar, 1500 parts; water, 8376 parts. The sugar is to be omitted in some cases.

† The student may profitably refer to Huxley and Martin's "Elementary Biology," Chap. IV., for directions in making his observations.

‡ Reess, in his "Botanische Untersuchungen über die Alcoholgährungspilze," 1870, calls this process the formation of ascospores, the mother-cell he calls an ascus, and the daughter-cells true ascospores. Accordingly he considers these plants to be very simple Ascomycetes!

280.—It was formerly held that the yeast plant was only the immature condition of a mould;* but Brefeld's researches,† which were undertaken to determine whether true yeast ever develops into a filamentous form, appear to be decisive against that view. He found that under different conditions, as with free access of air, or growth in a thin stratum of a neutral solution, the results were always negative, and no filamentous forms appeared.

(*a*) Examinations of the yeast plant are easily made by placing a very small drop of active yeast upon a glass slide, and, after covering it in the usual way, keeping it in a warm and moist chamber for some hours, at the end of which time the "budding" will have become quite well marked. A slide so prepared may be examined immediately, but with less satisfactory results.

(*b*) Yeast may be grown in abundance by placing a few drops in a quantity of Pasteur's solution, in which it grows with great rapidity in a temperature of 30° to 35° C. (about 90° Fahr.).

(*c*) The state in which daughter-cells are formed may be developed by growing the yeast-cells (those called bottom yeast are the most satisfactory) upon fresh-cut slices of potato, kohl-rabi, carrot, or, better still, upon small slabs of plaster of Paris. The preparations must be kept moist by covering with a bell-jar; with proper care the formation of daughter-cells will be seen in a week or ten days from the beginning of the experiment.

(*d*) In order that the study of these organisms may be at all satisfactory the student should be provided with high powers of the micro scope, say from 600 to 800 diameters.‡

§ III. Class Cyanophyceæ.

281.—These are blue-green, verdigris-green, brownish green, or rarely purple or red Protophytes, which, in addition to chlorophyll, contain a soluble coloring-matter—

---

* "Yeast is, in fact, nothing more than a peculiar condition of a species of *Penicillium*, which is capable of almost endless propagation without ever bearing perfect fruit." Berkeley's "Introduction to Cryptogamic Botany," 1857, p. 299.

† In *Flora*, 1873.

‡ The student is again referred to Huxley and Martin's "Elementary Biology;" in Chap. I. will be found a valuable account of the yeast plant, with directions for making examinations.

phycocyanine—and a less soluble one—*phycoxanthine.** Structurally the members of this class differ but little from the Schizomycetes, although they are of a much larger size. The cells generally show a little more coherence than in the last class.

They live in fresh or stagnant water, or upon damp ground, rocks, or decaying wood. Unlike the Schizomycetes, they do not normally inhabit putrid solutions.

282.—Order Chroococcaceæ. This is made up of unicellular plants. The cells, which are spherical, oblong, cylindrical, or angular, are either single, or more commonly united by a common jelly into families. Cell-division (in reality internal cell-division) takes place in either one, two, or three planes (Fig. 147).

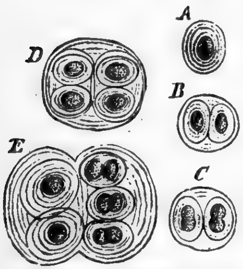


Fig. 147.—*Glœocapsa* in different stages of growth, showing mode of cell-multiplication. The daughter-cells are surrounded by the gelatinous walls of the mother-cells. *A*, youngest; *E*, oldest stage. × 300.—After Sachs.

Thirteen genera are known in the United States: (1) *Chroococcus,* with globose, oval, or angular (from pressure) cells, which are solitary or in free families; our four species grow on wet rocks or in springs; (2) *Glœocapsa* (Fig. 147), with spherical cells, which are solitary or in enclosed families; our eleven species form a firm grumous or gelatinous coating of a light brown color on wet rocks; (3) *Clœosphærium,* with very small cells, forming a thallus-like mass; we have one species, forming a light-colored scum on stagnant water; (4) *Merismopedia,* with globose, oval, or oblong cells, which occur in tabular families of four, eight, sixteen, etc.; our two species inhabit streams and fresh ponds. *Clathrocystis, Anacystis,* etc., are common.

283.—Order Nostocaceæ. The plants of this order are

---

* Phycocyanine, the blue coloring-matter, is extracted from the crushed plants by cold water; the solution is blue by transmitted and blood-red by reflected light. After the extraction of phycocyanine, treatment of the crushed plants with strong alcohol produces a green solution which contains chlorophyll, and a yellow coloring-matter, phycoxanthine; the latter may be separated by shaking up with the green solution a large quantity of benzine, which takes up the chlorophyll, and when at rest rises and forms a green upper layer containing chlorophyll, below which is the yellow alcoholic solution of phycoxanthine.

composed of rounded cells loosely united into a filament and generally imbedded in jelly (Fig. 148, *A*); they frequently form large masses, united by the glutinous jelly. At intervals in the filaments there are larger clear cells—the heterocysts—which appear from analogy to be reproductive bodies, although nothing is positively known as to their function. The usual mode of reproduction is by the simple fission of the cells. New masses or colonies are formed by the breaking up of the old filaments into pieces composed of a few cells, which then become endowed with a power of motion which consists of a slow bending from side to side with a forward movement at the same time. Each moving filament, when it comes to rest, may become the centre of a new colony, which arises from it by fission.

Six genera and thirty or more species are known in the United States. The principal genus is *Nostoc* (Fig. 148, *A*); its species form jelly-like masses from the size of a pin-head to several inches in diameter in ponds and streams, adhering to sticks and twigs, and on wet rocks or wet ground; they even grow inside of other plants—*e.g.*, *Anthoceros lævis*—and, according to the present view, constitute the so-called gonidia of certain lichens.

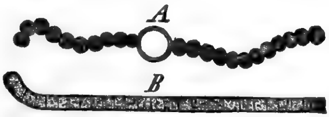


Fig. 148.—*A*, a filament of a *Nostoc*, with a large heterocyst; *B*, end of filament of *Oscillatoria*. × 300.—After Prantl.

284.—Order Oscillatoriaceæ. The filaments in this order are composed of more closely cohering cells than in the previous one; the cells unite by broad surfaces to form a rigid, cylindrical, straight or slightly curved filament (Fig. 148, *B*). They form dark-green, loose, or felted masses in water or on wet earth, and are remarkable for the peculiar oscillating movements of their filaments. No other method of reproduction than by fission is known.

The principal genus is *Oscillaria,* of which we have about thirty species.

285.—Order Rivulariaceæ. The filaments in this order present a greater differentiation than in any of the preceding; they are usually arranged in a radiating manner, and imbedded in a common jelly, so as to form small rounded

masses. Each filament has a basal cell (which is spherical and thick walled), and sometimes interstitial ones; the principal cells of the filaments are usually cylindrical and often much elongated; at the outer end they become attenuated into long slender hyaline hairs. Special reproductive bodies, called resting spores, are formed before the close of the growing season; these appear just above the basal cells, one on each filament, and are much larger and thicker walled than the remaining cells. Upon the death of the mass of filaments the resting spores remain, and from these upon the advent of favorable conditions new filaments are developed.

Five genera are known in the United States, the principal ones being *Rivularia, Calothrix,* and *Mastigonema;* their species are found in water or wet places everywhere; they also constitute the so-called gonidia of lichens.

286.—Order Scytonemaceæ. In this order the differentiation becomes so great that the filaments may be said to attain a distinct individuality; they branch here and there, and are furnished with thick-walled heterocysts, which are basal or interstitial. In this order there is also a well-developed sheath surrounding each filament, which may be compared with the poorly defined one of the preceding orders. The filaments form little masses or mats, growing in the water or on wet ground, or even on the moist bark of trees.

We have five genera, the principal one of which is *Scytonema*, which contains nineteen species. Some of these are the "gonidia" of lichens.

287.—Closely related to the foregoing orders, but not falling within the class Cyanophyceæ, is the doubtful order *Palmellaceæ.* The cells are single or in colonies, and imbedded in a gelatinous matter, much as in the Chroococcaceæ; but the cells are destitute of phycocyanine or phycoxanthine, containing only chlorophyll. This, however, is hardly a sufficient character for separating them. It is, moreover, not certainly known whether the forms included in this order are autonomous species; it seems probable that at least a portion of them are only early stages of other plants.

288.—The genera *Protococcus, Chlorococcum,* and one or two others, are probably to be placed near the Palmellaceæ, although their autonomy is doubtful also. They are all unicellular in the strictest sense of the term, and reproduce mainly by fission. In their resting stage they are spheroidal; in their motile stage they are provided with two cilia. The latter form is said to arise from the former by internal cell-division, which results in the production of "gonidia" of two sizes, the larger being termed macrogonidia, and the smaller microgonidia.

These organisms are common in shallow pools, in the gutters of roofs, and on the wet earth.

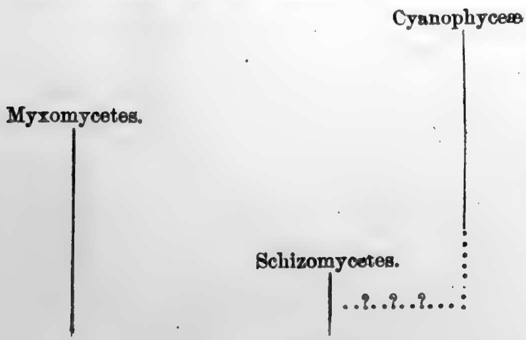
(*a*) For an account of the structure of Protococcus, with directions as to methods of study, see Arthur, Barnes and Coulter's "Handbook of Plant Dissection," p. 22.

(*b*) In the study of the Cyanophyceæ, and of other "fresh-water algæ," the student will find Rev. Francis Wolle's "Fresh-water Algæ of the United States" (1887) of great value.

(*c*) On account of their ready perishability, Protophytes are scarcely found in a fossil state. Schimper records a species of *Nostoc* from the Tertiary.

(*d*) The relationship of the classes of the Protophytes may be indicated by the following diagram:

ARRANGEMENT OF THE CLASSES OF PROTOPHYTA.



CHAPTER XV.

ZYGOPHYTA.

289.—This is an assemblage of quite simple plants, none of its members attaining any great degree of complexity. For the most part the plant-body consists of an elongated filament composed of united cells; sometimes, however, they form surfaces, and in other cases the plants are unicellular, or aggregated into communities. In these plants we find the first examples of undoubted sexuality, and throughout the group, the organs and methods of fertilization are nearly enough uniform to enable us to use them as distinguishing characters. The sexual organs all have this in common, that between the male and the female there is no appreciable difference as to form, size (with a few exceptions), color, origin, etc. In the sexual processes, likewise, there is this in common, that the result of the union of the two sexual cells is the production of a new cell, the *zygospore*, possessing very different characteristics from either. While the sexual cells have only ordinary walls, or none at all, the zygospores are covered with thick, firm walls.

290.—The zygospore is frequently called the "resting spore," because under certain circumstances it remains quiescent, while retaining its vitality, often for long periods of time. Thus at the close of the growing season, as upon the advent of the summer drought, or of winter, the zygospores fall to the bottom of the pools (in the aquatic forms), and in the dried or frozen mud remain uninjured until the return of favorable conditions, when they germinate and give rise to a new generation of plants.

291.—Nearly all the plants of this group contain chlorophyll, only one order being destitute of it. The green forms are all aquatic, and inhabit either fresh or salt water. They

include the greater part of the green algæ of our ponds and streams. Those which have no chlorophyll are saprophytes, and live upon dead organic matter. They are doubtless to be regarded as modified forms of some of the types of the chlorophyll-bearing portion of the group.

§ I. Class Zoosporeæ.

292.—This class is a somewhat doubtful one; it is composed of plants which, while differing in many other respects, agree in having locomotive sexual cells (*zoospores*). In this they agree, however, with the *Volvocineæ*, and bear a close resemblance to *Protococcus* and its allies. It is probable that a fuller knowledge of some of the plants of this class will result in their being distributed elsewhere.

The general structure of the plants referred to this class may be understood from the examples which follow. No attempt will be made here to indicate the orders to which they belong.

293.—*Pandorina* is a unicellular alga, which is united into colonies (called *cœnobia*), which swim about freely in the water (*A*, Fig. 149). Each colony consists of sixteen rounded or pointed cells (called *zoogonidia*), each provided with two cilia, and united into a spherical mass by a gelatinous envelope, through which the cilia project. Each zoogonidium breaks itself up into sixteen new zoogonidia, forming sixteen small and new colonies (*B*, Fig. 149), which are soon set free by the absorption of the common envelope of the colonies. The process of colony-formation just described is repeated again and again, thus giving rise, asexually, to a large number of colonies.

294.—The sexual process begins in the same way; but the zoogonidia of the new colony separate by the softening of the colony-envelope (*C* and *D*, Fig. 149), becoming zoospores, which are naked protoplasm-masses, which swim about by means of their cilia. After a time two zoospores meet, their points coming in contact, and their bodies soon fusing into one common body (*E, F, G*, Fig. 149). The result of this union, which is regarded as a very simple kind of sexual

act, is that within a short time a thick coat of cellulose is formed over the new cell, thus producing a *zygospore* (*H*, Fig. 149). After a long period of rest, these zygospores

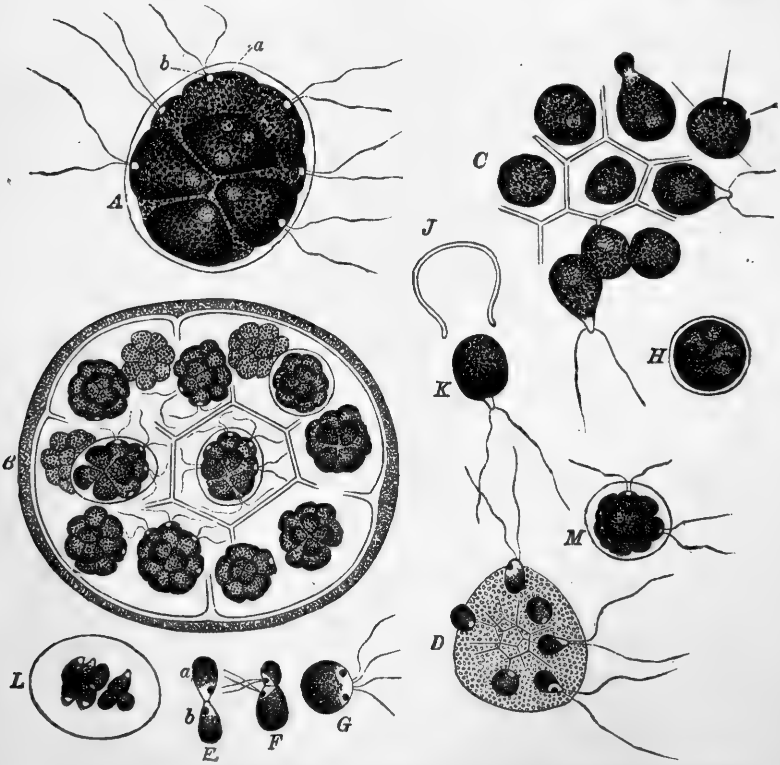


Fig. 149.—*Pandorina Morum.* *A*, non-sexual colony (or cœnobium) of 16 zoogonidia; *a*, red spot; *b*, transparent anterior end of zoogonidium, to which the two cilia are attached.
B, sixteen young sexual colonies about to leave the gelatinous wall.
C and *D*, colonies of sexual zoospores escaping.
E, *F*, *G*, conjugating zoospores
H, zygospore in resting stage (red).
J, *K*, germinating zygospore, the contents escaping as a large red ciliated swarm-spore.
L, new colony formed by the division of *K*, very young stage.
M, the same colony as *L*, in a further stage of development.—After Œrsted.

germinate by the bursting of the coat (exospore), when the protoplasmic contents escape as a ciliated swarm-spore (*K*, Fig. 149). After swimming about for some time, the swarm-

spores absorb their cilia, and surround themselves with a gelatinous envelope, when each breaks up into sixteen cells (zoogonidia) and gives rise to a new colony (*L* and *M*, Fig. 149).

Pandorina is nearly related to Volvox (see p. 243), from which it seems a violence to separate it. It occurs in pools of fresh water (in Europe) as minute green spherical cœnobia, 3 mm. (.012 inch) in diameter.

295.—*Hydrodictyon*, the Water Net, is a common plant in ponds and sluggish streams. It is, when full grown, a tubular net, composed of a multitude of elongated cells, which are attached only at their ends; the net sometimes attains a length of 25 to 30 centimetres (10 to 12 inches), and the cells which compose the meshes are in such specimens 7 to 8 mm. (⅓ inch) long.* The reproduction is as follows: The protoplasmic contents of certain cells break up into a large number of daughter-cells (macrozoogonidia), there being often as many as 7000 to 20,000; these soon arrange themselves within the mother-cell so as to form a miniature net (Fig. 150), which is freed by the absorption of the walls of the mother-cell. Under favorable conditions the young net attains full size within a month. A second mode of reproduction is known, or partly known. In certain cells, in the division of their protoplasmic contents, instead of giving rise to the comparatively large macrozoogonidia, they produce an extremely large number (30,000 to 100,000) of very small ciliated swarm-spores (zoospores, or the *chronizoospores* of Pringsheim), which, after swimming about for a time, acquire thick walls, and fall to the bottom of the water, where they remain in a resting state. Upon their germination they pass through a number of curious stages, and finally give rise to small nets. Suppanetz is said to have witnessed the conjugation of the swarm-spores within the mother-cell, or immediately after their emission.*

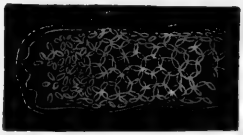


Fig. 150.—Part of a cell of *Hydrodictyon utriculatum*, in which the macrozoogonidia are beginning to arrange themselves so as to form a miniature net within the mother-cell.—After Œrsted.

---

* *Qr. Jour. Mic. Science*, 1875, p. 399.

296.—Closely related to *Hydrodictyon* is *Pediastrum* (Fig. 151), which consists of a number of cells arranged into a flat, thallus-like mass. The cells at a certain stage produce, by

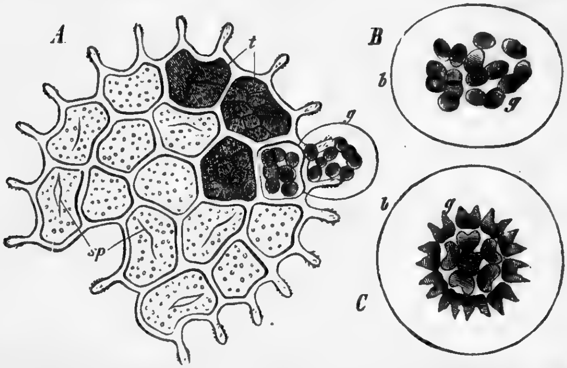


Fig. 151.—*A*, a colony of cells constituting a so-called individual of *Pediastrum granulatum*; *t*, cells with their contents remaining; the white cells are empty, their contents having escaped by the slits *sp*; *g*, contents of a cell (macrozoogonidia) escaping. *B*, macrozoogonidia *g*, in the motile state, enclosed in the membrane *b*. *C*, the macrozoogonidia arranging themselves in a colony, still enclosed by the membrane *b*. × 400.—After Braun.

internal cell-division, a large number of daughter-cells, which are of two sizes. The function of the smaller ones is unknown; the larger ones (macrozoogonidia) escape by a slit in the wall of the mother-cell, surrounded by a thin membrane, in which they swim freely for a time (Fig. 151 *B*). After a while they lose their power of motion and arrange themselves symmetrically, as in *C*, Fig. 151. They soon grow together, and thus form a colony like the parent one.

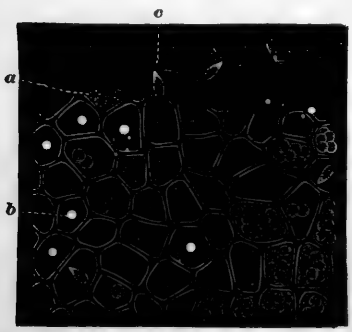


Fig. 152.—Portion of the thallus of *Ulva*. *a*, cells filled with zoospores (zoogonidia); *b*, opening in cell-wall, by which the zoospores escape from the cells; *c*, zoospores (zoogonidia).—After Œrsted.

297.—In *Cladophora* (one of the common Confervaceæ) the cells of the branching filaments break up into ciliated zoospores which directly

reproduce new filaments. Smaller bodies—swarm-spores—are also produced, and these are said to conjugate.*

298.—In *Ulva* the plant-body is flat, and composed of a single layer of polyhedral cells, in which are found zoospores, which are asexual (Fig. 152, *c*), and smaller swarm-spores, which are said to conjugate.† [See foot-note on p. 242.]

§ II. CLASS CONJUGATÆ.

299.—In this class the sexual process is a distinct conjugation, and it always takes place in the mature plant. Swarm-spores are wanting. The orders of this class are well marked.

300.—Order Desmidiaceæ. The Desmids are minute unicellular algæ; the cells are of very various forms, mostly more or less constricted in the middle, and divided into two symmetrical half-cells; they are free, or united into loose families, sometimes involved in a jelly. The cell-wall is more or less firm, but not silicious.

301.—The reproduction of Desmids takes place asexually and sexually. In the first the neck uniting the two halves of the cell elongates and becomes divided by a transverse partition, so that instead of the original symmetrical cell there are now two exceedingly unsymmetrical ones; these grow by the rapid enlargement of the new and small halves; eventually the two cells become symmetrical, by which time they have separated. This process, which is essentially fission, may be repeated again and again.

The sexual process takes place in this way: each of two cells which are near one another sends out from its centre a conjugating tube, which meets the corresponding one from the other (*d*, Fig. 153). At the point of meeting the two tubes swell up hemispherically, and finally, by the disappearance of the separating wall, the contents unite and form a rounded zygospore (*e*, Fig. 153), which soon becomes

* and †. Areschoug, in "Observationes Phycologicæ," 1874, records having seen the conjugation in *Cladophora* and *Ulva*.

coated with a thick wall (*f*, Fig. 153). This zygospore is a resting spore, and may retain its vitality for an indefinite period.

302.—In the germination of the zygospore the first noticeable change is the partial separation of the contents into two portions, and the escape of the whole, surrounded by a delicate wall, through a rent in the exospore (*g, h,* Fig. 153); the separation of the protoplasm now becomes complete (*i*, Fig. 153), and each portion becomes again partly divided by lateral constrictions, which, however, do not quite reach the centre; in this way, within the mass which escaped from the zygospore there are formed two constricted cells, which

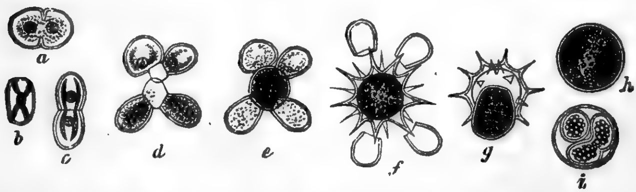


Fig. 153.—Conjugation of *Cosmarium Menenghinii*. *a*, front; *b*, end; *c*, side view of the adult plants; *d*, two cells conjugating; *e*, young zygospore formed; *f*, ripe zygospore, with spiny wall—the four halves of the parent cells are empty; *g*, the zygospore germinating after a period of rest; *h*, the young cell escaped from zygospore; *i*, young cell dividing, showing two new plants similar to *a*, placed crosswise in the interior of the cell. × 475.—After Œrsted.

are, in fact, new individuals resembling the original ones which conjugated (*a, b, c,* Fig. 153).

The descriptions above given are of the processes as they take place in the bilobed Desmids; in those which are not lobed it takes place in essentially the same way, with differences only in the minor details.

303.—Desmids have the power of slow locomotion, and they may often be seen moving across the field of the microscope, or in a jar or bottle they may frequently be seen to congregate in particular places. The mechanism of the movement is unknown, but it appears to be certain that it is not ciliary.

Desmids are exclusively inhabitants of fresh water (not salt), and in almost all cases they appear to prefer pure and

clear water to that which is stagnant, although they are to be found in the latter also.

The principal genera are *Cosmarium* (Fig. 153), *Euastrum* and *Micrasterias*, which are constricted in the middle; and *Closterium*, in which the individuals are cylindrical or fusiform.*

304.—Order Diatomaceæ.† The Diatoms are microscopic unicellular algæ, resembling in many particulars the Desmids, but differing from them in having walls which are silicified, and in the chlorophyll being hidden by the presence of phycoxanthine. The endochrome, as the colored contents are called, is always symmetrically arranged. Each cell (technically called a frustule) is usually composed of two similar and approximately parallel portions, called the valves. Each valve may be described as a disc whose edge is turned down all around, so as to stand at right angles to the remainder of the surface, making the valve have the general plan of a pill-box cover. The two valves are generally slightly different in size, so that one slips within the other (*A*, Fig. 154), thus forming a box with double sides. In other cases—as, for example, in *Diatoma* and *Fragilaria*—the valves are simply opposed, and do not overlap. In figures and descriptions of Diatoms, the parts corresponding to the top and bottom of a box are referred to as the valves, or as the *side view* (*C*, Fig. 154), and that which in the box would be called the side, is in the Diatom called the *front*.

305.—The individuals may exist singly, or in loose families; they are free, or attached to other objects by little stipes, and they are frequently imbedded in a mucous secretion. The free forms are locomotive, and may be seen in constant motion under the microscope. As in the Desmids, the mechanism of this movement is not certainly known;

---

* The student is referred to Rev. Francis Wolle's "Desmids of the United States," 1884, for an account of our species.

† Most of our species are figured and described in Henri Van Heurck's "Synopsis des Diatomées de Belgique," 1880–5.

the most probable explanation is that it is due to protrusions of the protoplasm through orifices in the rigid wall.

306.—Diatoms bear a close resemblance to the Desmids in their modes of reproduction; the differences that exist are easily referable to the differences in the wall. The asexual reproduction is a true fission, although at first sight it might not be recognized as such. The protoplasmic contents of the cells divide in a plane parallel to the valves; each portion then forms a new valve in the plane of the division. As during this process the two original valves are pushed apart, the new valves are fitted, the one into the larger and the other into the smaller one (*B*, Fig. 154). By a slight subsequent increase of their contents, the two daughter-cells are pushed out so as to be free from each other; in many cases they separate, while in others they remain in contact, although really free. This process requires from three to four days for its completion. It will readily be seen that the continued formation of individuals in this way must result, in all species whose valves are of a slightly unequal size, in producing smaller and smaller cells. This reduction of size does not, however, take place in those species whose valves are simply opposed, as in Diatoma. The reduction of size is corrected by the formation of what are termed *auxospores;* * these are large individuals, which form either by an asexual or a sexual process. The asexual formation of auxospores takes place by the

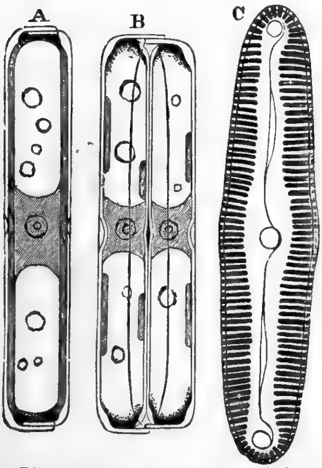


Fig. 154.—*Navicula viridis.* *A*, front view of a frustule; *B*, front view of a frustule undergoing fission; *C*, side view of a frustule, showing the central line, called the raphe, the central and terminal nodules, and the surface markings. —After Œrsted.

* From the Greek αὐξάνω, to increase.

protoplasm of one of the small Diatoms leaving its silicious shell (the latter falling apart), and then increasing by growth until it reaches the normal size, when it forms a new coat about itself. This is not unlike what has been called the Rejuvenescence of the cell. (See p. 42.)

307.—The second mode of the formation of auxospores is a sexual one, and is, in fact, the sexual mode of reproduction above referred to.* Two individuals come near each other; their valves separate, and the two protoplasm-masses unite with each other into one mass, or in many cases two masses (*A*, Fig. 155). These new masses develop directly into auxospores, the whole process requiring from ten to fourteen days (*B*, Fig. 155).

308.—Diatoms are exceedingly abundant; they occur in both salt and fresh water, usually forming a yellowish layer at the bottom of the water, or they are attached to the submerged parts of other plants, and to sticks, stones, and other objects; they have been dredged from the ocean at great depths, and appear to exist there in enormous quantities. They are also found among mosses and other plants on moist ground; great numbers occur as fossils, forming in many instances vast beds composed of their empty frustules. The varied and frequently very beautiful markings of their valves have long made Diatoms objects of much interest to the microscopist. The great regularity and the extreme fineness of the lines and points upon some, have caused them to be used as microscopic tests. The

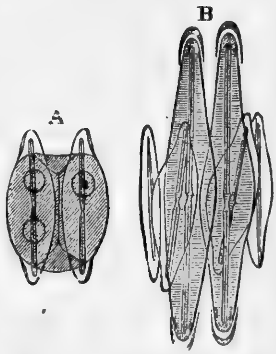


Fig. 155.—*Navicula saxonica*, showing conjugation and formation of auxospores. *A*, conjugation of two frustules; *B*, two auxospores, with the four valves of the two parent frustules.—After Œrsted.

---

* This process takes place at certain seasons of the year for each species; according to Professor H. L. Smith, in *Gomphonema olivaceum* it occurs in February and March.

fineness of some of these markings is astonishing, as will be seen from the following list :

**Pleurosigma Balticum*.............	.0006 mm.	(.000026 inch).
Pleurosigma angulatum...........	.0005 "	(.000019 "
Navicula rhomboides...............	.0004 "	(.000015 "
Amphipleura pellucida............	.0002 "	(.000008 "

(*a*) The classification of Diatoms is as yet largely artificial. That proposed by Professor H. L. Smith † is one of the most satisfactory ; it is based upon the structure of the frustule. He divides the order into three tribes, each containing several families, as follows :

TRIBE I. RAPHIDIEÆ.

Frustules mostly bacillar (*i.e.*, longer than broad) ; always with a distinct raphe or median line on one or both valves, and with central and terminal nodules ; without teeth, spines, awns, or processes.

Family 1. Cymbelleæ. Raphe mostly curved ; valves alike, more or less arcuate, cymbiform (*i.e.*, lunate).

Illustrative genera, *Amphora, Cymbella.*

Family 2. Naviculeæ. Valves symmetrically divided by the raphe ; frustules not cuneate or cymbiform.

Navicula (Figs. 154 and 155), *Stauroneis, Pleurosigma, Amphipleura.*

Family 3. Gomphonemeæ. Valves cuneate ; central nodule unequally distant from the ends.

Gomphonema, Rhoicosphenia.

Family 4. Achnantheæ. Frustules genuflexed ; nodule or *stauros* on one valve ; mostly stipitate.

Achnanthes, Achnanthidium.

Family 5. Cocconideæ. Frustules (generally parasitic) with valves unlike ; valves broadly oval.

Cocconeis, Anortheis.

TRIBE II. PSEUDO-RAPHIDIEÆ.

Frustules generally bacillar (*i.e.*, longer than broad) ; valves with-

---

* These measurements are those given in Carpenter's work on "The Microscope," fifth edition, p. 212. Those given by Professor Morley, in *Am. Naturalist*, 1875, p. 429, are a trifle less in each case.

† "Conspectus of the Families and Genera of the Diatomaceæ," by H. L. Smith, published in *The Lens*, 1872–3, and republished in *Le Microscope, sa construction*, etc., by Henri Van Heurck, 1878.

The brief sketch of this system of classification here given is furnished by Professor Smith.

out a true raphe; without central and marginal nodules; without teeth, processes, or spines.

Family 6. Fragilarieæ. Frustules adherent, forming a ribbon-like, fan-like, or zigzag filament, or attached by a gelatinous cushion or stipe; sometimes arcuate in front, or side view.

Epithemia, Eunotia, Fragilaria, Synedra, Diatoma.

Family 7. Tabellarieæ. Frustules with internal plates, or imperfect septa, often forming a filament.

Climacosphenia, Grammatophora, Rhabdonema, Tabellaria, Striatella.

Family 8. Surirelleæ. Frustules alate, or carinate; frequently cuneate in front view and side view.

Nitzschia, Surirella, Cymatopleura.

TRIBE III. CRYPTO-RAPHIDIEÆ.

Frustules cylindrical or angular; frequently with processes, spines, teeth, or awns; and often coherent, forming a filament.

Family 9. Chætocereæ. Frustules mostly hyaline and armed with bristles or awns, and generally coherent.

Rhizosolenia, Chætoceros.

Family 10. Melosireæ. Frustules cylindrical, adhering and forming a stout filament; valves cylindrical, sometimes armed with spines.

Melosira, Stephanopyxis.

Family 11. Biddulphieæ. Frustules adherent, forming generally a zigzag filament, attached by one or two processes.

Isthmia, Terpsinoe, Biddulphia, Hemiaulus.

Family 12. Eupodisceæ. Frustules not forming a filament; valves cylindrical, with ocelli; often with radial ribs or furrows.

Auliscus, Aulacodiscus, Eupodiscus.

Family 13. Heliopelteæ. Valves divided into compartments alternately light and dark, often with marginal spines or teeth.

Actinoptychus, Heliopelta, Halionyx.

Family 14. Asterolampreæ. Valves circular (rarely angular) and mostly hyaline, with linear, often bifurcating, rays.

Actinodiscus, Mastogonia, Asterolampra.

Family 15. Coscinodisceæ. Valves circular, generally with radiating cellules, granules, or punctæ; sometimes with marginal or intra-marginal spines or distinct ribs; without distinct processes.

Cyclotella, Actinocyclus, Stephanodiscus, Arachnoidiscus, Coscinodiscus.

(*b*) Diatoms are very easily obtained for study; it is only necessary to scrape off a little of the slippery covering of submerged stones or sticks to procure numerous specimens. They may be obtained also from ordinary drinking water, allowing it to flow from a hydrant through a filter of "Canton flannel" for an hour or so. Often appar-

ently pure water placed for a few weeks in a clean bottle and exposed to the light will yield an abundant crop, generally of one species.

309.—Order Zygnemaceæ. The plants of this order are elongated unbranched filaments, composed of cylindrical cells arranged in single rows. The cells are all alike, and each one appears to be independent, or nearly so, of its associates. The filament is thus, in one sense, rather a composite body than an individual. Each cell has usually a centrally placed nucleus, with radiating extensions of the protoplasm passing from it to the layer lining the inner surface of the wall. The chlorophyll is generally arranged in bands or plates, but under certain conditions it exists in shapeless masses.

310.—The vegetative increase of the number of cells takes place by the fission of the previously formed cells. The protoplasm in a cell divides, and a plate of cellulose forms in the plane of division. This is repeated again and again, and by it the filament becomes greatly elongated. It is interesting to note that this increase of cells, which here constitutes the growth of the plant-body, is that which in simpler plants is called the asexual mode of reproduction. In the plants under consideration there is barely enough coherence of the cells to enable them to constitute a plant-body, and one can readily see that the same fission of the cells which now takes place, and which here increases the *size* of the plant, would, if the cells cohered less, simply increase the *number of individuals.*

As might be expected, the filaments occasionally separate spontaneously into several parts of a considerable length, and the parts floating away give rise to new filaments. The separation takes place by the cells first rounding off slightly at the ends, so that their union is weakened at their corners; finally only the centres of the rounded ends are left in slight contact, which soon breaks.

311.—The sexual reproduction is well illustrated in *Spirogyra,* one of the principal genera. At the close of their growth in the spring, the cells push out little processes from their sides, which extend until they come in contact with

similar processes from parallel filaments (*a*, *b*, Fig. 156). Upon meeting, the ends of the processes flatten upon each other, the walls fuse together, and soon afterward become absorbed, thus making a channel leading from one cell to the other (Fig. 157). Through this channel the proto-

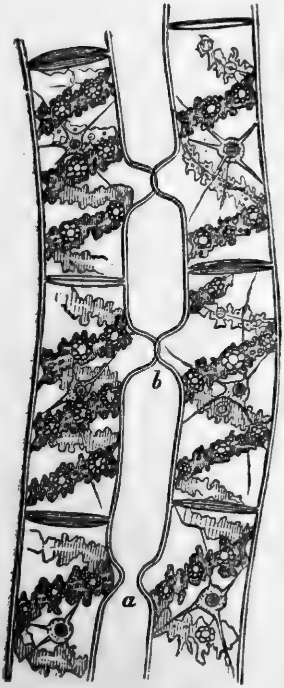


FIG. 156.

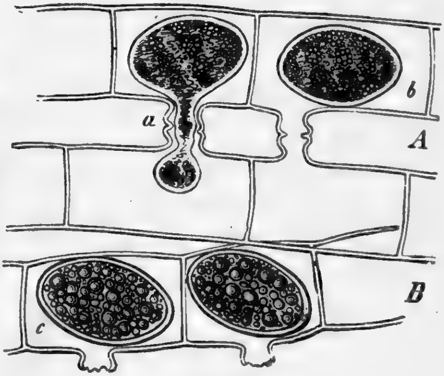


FIG. 157.

Fig. 156.—Beginning of the process of conjugation in *Spirogyra longata*. *a*, beginning of the formation of lateral tubes; *b*, *c*, the tubes in contact. × 550. —After Sachs.

Fig. 157.—Conjugation of *Spirogyra longata*. *A*, the protoplasm passing from one cell to the other at *a*; *b*, the mass of protoplasm formed by the union of the protoplasmic contents of the two cells.

B, two young zygospores (*c*), each with a cell-wall. They contain numerous oil drops, and are still enclosed by the walls of the parent cell. × 550.—After Sachs.

plasm of one cell passes into the other, and the two fuse into one mass, which becomes rounded, and in a short time secretes a wall of cellulose around itself (Fig. 157, *A* and *B*). The zygospore thus formed is set free by the decay of the dead

cell-walls of the old filament surrounding it; it then falls to the bottom of the water and there remains until the proper conditions for its growth appear.

312.—The conjugation described is the one best known; it prevails in a large part of the genus mentioned. There are some curious modifications of the process. In what is called genuflexous conjugation the opposing cells of parallel filaments become strongly bent back so as to form an angle at their central points; then the angles approach each other and fuse, allowing the cell-contents to pass over, as in the other case.

Lateral conjugation takes place between the cells of the same filament. At the contiguous ends of two cells tubular processes are pushed out, which, meeting, form a curved channel from one cell to the other. Occasionally there appears to be only a slight enlargement of the contiguous ends of the cells, and this is followed by the breaking away of a portion of the separating wall. These cases of lateral conjugation show that the cells are, to a great extent, to be regarded as independent organisms, and that the conjugation is primarily the union of two cells, instead of two filaments.

313.—The germination of the zygospore is a simple process. The inner mass enlarges and bursts the outer hard coat; it then extends into a columnar or club-shaped mass, gradually enlarging upward from its point of beginning; after a while a transverse partition forms in it, and this is followed by another and another, until an extended filament is formed.

(*a*) The principal genera are *Spirogyra*, in which the chlorophyll bands are spirally arranged in the cells, and *Zygnema*, in which the chlorophyll is usually arranged in a stellate manner. Thirty-nine species of *Spirogyra* are recorded as occurring within the United States, and of these *Sp. longata* and *Sp. quinina* are the most common. Of *Zygnema* six species are recorded in the United States, several of which are common.

(*b*) These plants may be found at any time in ditches and streams, where they often form extensive masses of green felt; but it is only from the middle to near the end of spring that they can be found in conjugation. For the Northern States the time varies from April to the first of June; in the South it is of course much earlier, being in

Florida as early as February. In searching for conjugating specimens only the yellow and brown masses of filaments need be examined, as the process never takes place in the bright green ones.

314.—In the genera *Mesocarpus* and *Pleurocarpus* the conjugation is slightly different from that described above. The conjugating tube, which is much longer, becomes dilated midway between the two filaments, and in this the contents of the two cells unite and form a zygospore. This difference has been considered by some botanists to be of sufficient importance to set off these genera in a group allied to, but distinct from, the Zygnemaceæ. When they are so set off they constitute the *Mesocarpeæ ;* but it is altogether probable that they are to be considered rather as a subdivision of the Zygnemaceæ than as a distinct order.

Mesocarpus scalaris is our most common species. In general appearance it resembles the previously mentioned species, but its chlorophyll is not so regularly arranged.

315.—Order Mucorini. The Moulds are saprophytic and sometimes parasitic plants; they are composed of long branching filaments (*hyphæ*), which always form a more or less felted mass, the *mycelium ;* when first formed the hyphæ are continuous, but afterward septa are formed in them at irregular intervals. The protoplasmic contents of the hyphæ are more or less granular, but they never develop chlorophyll. The cell-walls are colorless, except in the fruiting hyphæ, which are usually dark colored or smoky (fuliginous). The mycelium sometimes develops exclusively in the interior of the nutrient medium ; in other cases it develops partly in the medium and partly in the air. In some species the mycelium may occasionally attach itself to the hyphæ of other plants of the same order, and even to nearly related species, and derive nourishment parasitically from them. It is doubtful, however, whether any Moulds are entirely parasitic, and so far as parasitism occurs it appears to be confined to narrow limits ; none, so far as known, are parasitic upon higher plants.

316.—The reproduction of Moulds is asexual and sexual. In the asexual reproduction the mycelium sends up erect

hyphæ, which produce few or many separable reproductive cells—the spores (Fig. 158). The method of formation of the spores in *Mucor Mucedo* is as follows: the vertical hyphæ, which are filled with protoplasm, become enlarged at the top, and in each a transverse partition forms (*A, a,* Fig. 159), the portion above the partition (*b,* Fig. 159) becomes larger, and, at the same time, the transverse partition arches up (*B, a,* Fig. 159), finally appearing like an extension of the hypha, then called the *Columella* (*C, a,* Fig. 159). The protoplasm in the enlarged terminal cell (*b*) divides into a large number of minute masses, each of which surrounds itself with a cell-wall; these little cells are the spores, and the large mother-cell is now a sporangium.

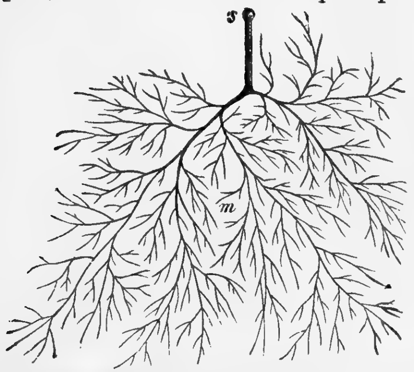


Fig. 158.—Diagram showing the mode of growth of *Mucor Mucedo.* *m*, the mycelium; *s*, single sporangium, borne on an aerial erect hypha.—After Prantl.

In the other Moulds the process is essentially like that in *Mucor Mucedo.* In many cases there are several sporangia formed at the top of the vertical hyphæ; in such cases the latter are branched before the formation of sporangia. Another variation from the method as described above is that in some species but one spore is formed in each sporangium; the hyphæ then appear to bear naked spores.

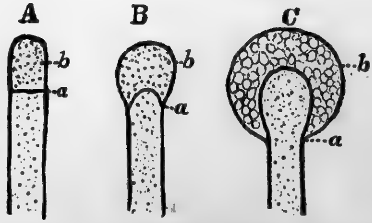


Fig. 159.—Diagrams showing mode of growth of the sporangium of *Mucor Mucedo.* *A*, very young stage; *B*, somewhat later; *C*, sporangium with ripe spores. *a* in all the figures represents the partition wall between the last cell of the filament and the sporangium *b*.

317.—The spores are set free in different ways; in some cases the wall of the sporangium is entirely absorbed by the time the spores are mature; in other cases only portions of

the sporangium-wall are absorbed, producing fissures of various kinds—*e.g.*, at the base in *Pilobolus;* about the middle in *Circinella;* irregular in *Mucor*, etc. The spores germinate readily when on or in a substance capable of nourishing them (but not in pure water); they send out one or two hyphæ (sometimes one from each end), which soon branch and give rise to a mycelium. Spores may, if kept dry, retain their vitality for months.

318.—A second kind of asexual formation of spores takes place in some, if not all, the genera of the Mucorini. The

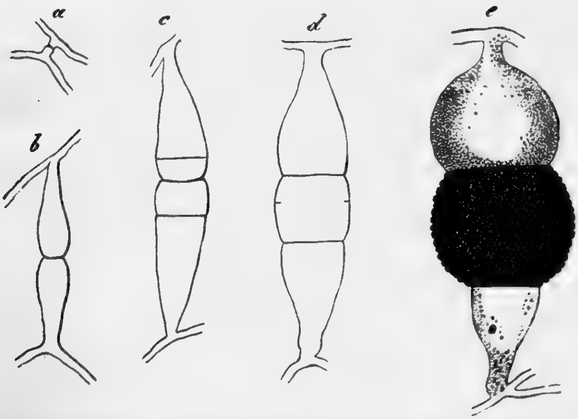


Fig. 160.—Conjugation of *Mucor stolonifer*. *a*, two hyphæ near each other, and sending out short lateral processes or branches, which come in contact; *b*, the branches grown larger; *c*, the formation of a partition near the end of each branch; *d*, absorption of the wall between the two branches, and the consequent union of the protoplasm of the end cells; *e*, zygospore fully formed. *e* × 90; the others nearly the same.—After De Bary.

protoplasm in certain parts of the hyphæ condenses and becomes transformed into single reproductive bodies, known as *chlamydospores.* Occasionally they form at the ends of hyphæ, and are then apt to be mistaken for the "fruiting" of other fungi.

319.—Sexual reproduction takes place after the production of asexual spores; the mycelium produces at particular points, in the air or within the nutritive medium, two similar branches, which come in contact with each other, and by fusing their contents give rise to a zygospore (Fig. 160).

The steps in the process in *Mucor stolonifer* are briefly as follows: two hyphæ come near each other, and send out small branches, which come in contact with each other (*a*, Fig. 160); these elongate and become club-shaped, and at the same time they become more closely united to each other at their larger extremities (*b*, Fig. 160); a little later a transverse partition forms in each at a little distance from their place of union (*c*, Fig. 160); the wall separating the new terminal cells is now absorbed, and their protoplasmic contents unite into one common mass (*d*, Fig. 160); the last stage of the process is the secretion of a thick wall around the new mass, thus forming a zygospore (*e*, Fig. 160, and *z*, Fig. 161).

It is interesting and instructive to note here the close similarity between the zygospore of *Mucor stolonifer* and that of *Mesocarpus*, briefly described above (par. 314). In both the zygospore is formed *in the lateral branches* of the ordinary filaments.

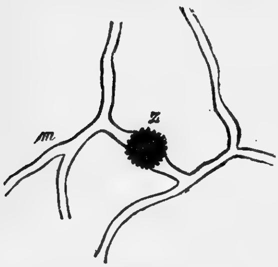


Fig. 161.—Zygospore, *z*, of *Mucor; m*, mycelium.—After Prantl.

320.—In *Piptocephalis* the formation of the zygospore is essentially like that in *Mucor*, with some minor differences. The uniting hypha-branches are large and curved, and are smaller at their points of union; the zygospore is formed at first in the small neck formed by the union of the tips of the branches, but it soon grows so much as to appear to be external (*Z*, Fig. 162). In this, as in all other cases, however, the zygospore is strictly an endogenous formation.

"The zygospore does not germinate until it has undergone desiccation, and has experienced a certain period of rest,"* when, if placed in a moist atmosphere, it sends out hyphæ which bear sporangia. The zygospores appear never

* "Researches on the Mucorini," by Ph. Van Tieghem and G. Le Monnier (translated in *Quarterly Journal of Microscopical Science*, 1874, p. 49), upon which most of what is here said about the Moulds is based.

to form a mycelium; that is always the result of the growth of spores from the sporangia.

(*a*) In the study of the Moulds it is almost always necessary to make use of alcohol for freeing the specimens of air; afterward they usually

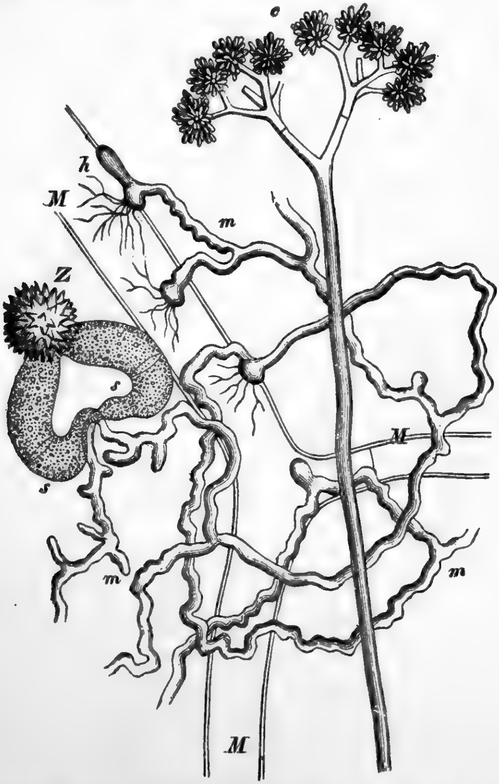


Fig. 162.—*Piptocephalis Freseniana*, parasitic upon the hyphæ, *M*, *M*, *M*, of *Mucor Mucedo*. *m*, *m*, parasitic hyphæ, attached to their host by the haustoria, *h*; *c*, conidial spores; *s*, *s*, the two branches which conjugate and form the zygospore, *Z*. Highly magnified.—After Brefeld.

require to be treated with a dilute alkali, as a weak solution of ammonia or potassic hydrate, which causes the hyphæ to swell up to their original proportions before drying; care must be taken that the hyphæ and spores are not unduly swollen, or serious mistakes may be made.

(*b*) In the careful study of the Moulds it is necessary to resort to artificial cultures of the different species, in order to be able to follow them

through all their changes. The spore of a particular species must be sown, and the development of hyphæ, mycelium, sporangia, etc., carefully followed; and the greatest care must be taken to guard against error from the accidental presence of other species.

(*c*) "Pan culture," which consists in sowing the spores upon or in the nutritive medium in pans or deep plates covered by bell-jars, must always be resorted to, even if more accurate cultures are also made. By placing a quantity of horse-dung in a pan under a bell-jar, there will soon be obtained a good supply of vigorous Moulds; sometimes several species may be obtained from a single pan. By care a few sporangia of each species may be obtained from this first culture, with little probability of contamination with other species. These are to be used for more careful cultures.

(*d*) If now moistened pieces of fresh bread are placed under a bell-jar, and a few of the spores of a particular species are sown on them, the growth and successive stages of development may be easily followed. Instead of bread, other materials may be used, as stewed prunes and other fruits, pieces of oranges or lemons, etc., and for certain species the half-cleaned bones of beef from the kitchen.

(*e*) Where still greater care is desirable, the nutritive media may be prepared by boiling and filtering, after which they are placed in thoroughly cleaned pans or plates, and covered by clean bell-jars; in these are placed pieces of hardened plaster of Paris or earthenware (porous), which have previously been heated so as to destroy all spores, and upon them are sown the selected spores. The sources of error are in this way very much reduced, but it must be borne in mind that they are by no means all eliminated; hence the student must be constantly on the lookout for other species than the one under culture.

(*f*) The media recommended by Van Tieghem and Le Monnier are, (1st) boiled and filtered orange juice, which, being acid and saccharine, is not so liable to be invaded by other common Moulds; (2d) a decoction of horse-dung, boiled and filtered; this is neutral and alkaline, and serves as a medium for many species; but it is open to the objection that it is liable to the invasion of intruding species; (3d) a saline solution of the following composition:

Calcium nitrate	4 parts.
Potassium phosphate	1 "
Magnesium sulphate	1 "
Potassium nitrate	1 "
Distilled water	700 "
[Sugar	7 parts.]

In some cases the sugar may be omitted.

(*g*) The most accurate and satisfactory, but at the same time most difficult cultures, are cell-cultures. These are made as follows: glass, tin, or India-rubber rings four to five millimetres high are fastened to

ordinary glass slides; a very little water is placed in the bottom of the cell so formed, to keep the air in it always moist; a small drop of the nutrient liquid, free from spores of any kind, is placed in the middle of a cover-glass of the proper dimensions, and in this a single spore of some particular Mould is placed; the cover-glass is now inverted over the cell, and held in place by a minute quantity of oil on the edge of the cell. The preparation must be placed in a warm and saturated atmosphere. An ordinary bell-jar set over a plate of water, or better still, of wet sand, will furnish a very good moist chamber. The apparatus used by Van Tieghem and Le Monnier is, however, in many respects the best that has yet been devised (Fig. 163).

By means of such cultures as this, the student may follow all the details of the germination, and after-development of any particular spore, as all that is necessary to do is to remove the slide from the growing box, and, without disturbing the cell, to place it under the microscope; the same specimen may thus be examined any number of times, with the least possible liability of error.

(*h*) The most common Moulds are species of the genus *Mucor*. *M.*

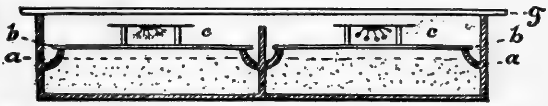


Fig. 163.—Section of apparatus for cell cultures. The shaded portion represents a section of a tin or zinc box; *a*, *a*, the supporting ledges; *b*, *b*, the glass slips; *c*, *c*, glass or metal rings fastened to the glass slips, seen in section, and covered with a piece of thin glass; *g*, plate of glass, covering the box. The dotted line shows the height of the moist sand with which the bottom of the box is covered.

Mucedo and *M. stolonifer* (if distinct) are common on many decaying substances. *M. Syzygites* occurs on decaying Agarics and *Polypori*. *Pilobolus crystallinus*, *Piptocephalis Freseniana*, and *Chætocladium Jonesii* occur on animal excrement. *Phycomyces nitens* grows on oily or greasy substances, as old bones, oil casks, etc.

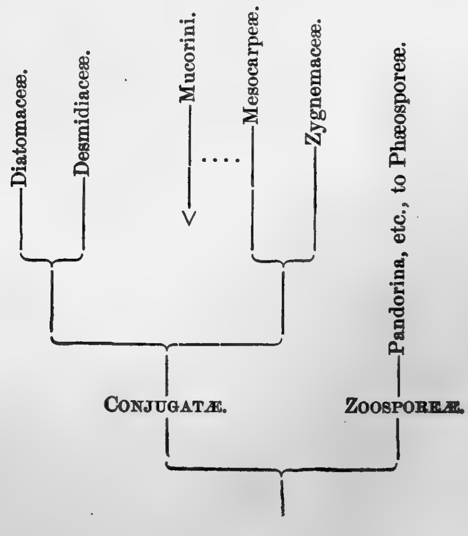
(*i*) The Moulds are evidently related to the Mesocarpeæ in their sexual reproduction, which is the most important, as it is the most constant. The conidia of Moulds are clearly homologous with the zoospores, of the Zoosporeæ, being nothing more than aerial modifications of them. The non-septated condition of the filaments of the Moulds does not constitute so great a difference between them and the filaments of the green Conjugatæ as might at first be imagined; in the germination of the zygospore of *Spirogyra* it will be remembered that the filament elongates quite a good deal before a septum forms in it; between this and the very late formation of septa, as in the Moulds, the difference is only one of degree. The Moulds may then be looked upon as Mesocarpous Conjugatæ which have lost their chlorophyll through their saprophytic habits, and which have otherwise undergone slight modifications mainly correlated with their aerial habits.

The PHÆOSPOREÆ, containing the kelp and its allies, are marine plants of an olive-brown color, varying greatly in size and structure, from minute filamentous forms to the gigantic kelp with stems and leaves, often a hundred metres or more in length. In previous editions they were regarded as more nearly related to the Fucaceæ [p. 264], but their reproduction by the conjugation of similar zoospores indicates their relationship to the zygophytic zoosporeæ. They include the highest plants of the class.

Twelve families, viz., Scytosiphoneæ, Punctarieæ, Desmarestieæ, Dictyosiphoneæ, Ectocarpeæ, Sphacelarieæ, Leathesieæ, Chordarieæ, Asperococceæ, Ralfsieæ, Sporochneæ, Laminarieæ, are represented on the New England coast by twenty-six genera and forty-eight species, while many more occur on the Pacific coast, where the great bladder kelp (*Macrocystis pyrifera*) sometimes attains a length of two hundred metres or even more.

Fossil Zygophytes.—In the Silurian period species of *Laminarites, Harlania*, etc., probably represented the Phæosporeæ, which order was also abundantly represented in the Devonian. *Confervites* occurs in the Jurassic, and in the Tertiary. Fossil diatoms of many species have been found in the Tertiary; at Richmond, Va., they form a vast bed nearly ten metres thick, and one at Monterey is sixteen metres in thickness.

ARRANGEMENT OF THE CLASSES AND ORDERS OF ZYGOPHYTA.



CHAPTER XVI.

OOPHYTA.

321.—The distinguishing feature of the plants belonging to this division is that they develop a large cell (the *oogonium*), differing from those about it in size and general appearance, which contains one or more rounded masses of protoplasm (the *oospheres*), which are subsequently fertilized by the contents of a second kind of special cell of much smaller size (the *antheridium*). The oogonium is the female reproductive organ, and the antheridium the male. The protoplasm of the latter is in some cases transferred by direct contact to the oosphere; in other cases it is first broken up into motile bodies, the spermatozoids, which then come to and become fused with the oosphere. The oosphere itself is never motile, and in most cases it remains within the parent plant until long after it is fertilized. The result of fertilization is the production of an oospore, which differs from the oosphere structurally in having a hard and generally colored coating, and physiologically in having the power of germination and growth after a period of rest of greater or less duration.

322.—The plants of this division vary greatly as to the development of the plant-body. In some cases it is a feebly united colony (*Volvox* and its allies), while in its highest forms it is a well-developed thallus, with even the beginning of a differentiation into Caulome, Phyllome, and Root (*Fucaceæ*).

§ I. Volvox and its Allies.

323.—In the classification of the plants of this division the lowest place must be assigned to *Volvox* and *Eudorina*, which, as previously stated, are, with doubtful propriety,

separated from *Pandorina.* If the two genera are to be separated from *Pandorina* there can be but little doubt that their position must be in the very lowest part of the Oophyta. Such a position would indicate what is probable on other grounds also, that the divisions Zygophyta and Oophyta lie side by side as two divergent systems, and that in their lowest members they almost, if not entirely, coalesce.*

324.— *Volvox globator* is a hollow spherical colony of unicellular algæ, having a diameter of .5 to .8 mm (.02 to .03 inch). Each individual of the colony is a flask-shaped cell of green-colored protoplasm, bearing two cilia upon its pointed extremity, and surrounded by a hyaline gelatinous envelope. These individuals are arranged so as to form a spherical surface, their hyaline envelopes being in contact with one another, and so placed as to bring the pointed ends of the green masses, with their cilia, to the surface. The sphere is thus made up of closely approximated individuals, which dot its surface, and whose cilia give to the whole colony a hairy appearance. The movements of the cilia give to the sphere a rotary motion, which is usually one of progression also.

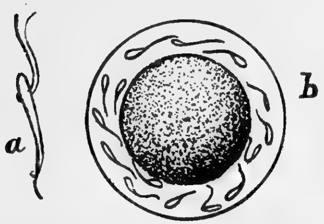


Fig. 164.— *Volvox globator.* *a*, spermatozoid, × 800. *b*, oogonium, with spermatozoids surrounding the oosphere, × 400.—After Cohn.

325.—The sexual reproduction of *Volvox* takes place in this way : some of the cells in a colony undergo conversion into spermatozoids, which are elongated club-shaped, and provided with two cilia (*a*, Fig. 164) ; other cells of the same colony, or of different colonies, become greatly enlarged into oogonia, consisting of an outer hyaline coat enclosing an inner rounded mass of dense and granular protoplasm (*b*, Fig. 164). Upon the escape of the spermatozoids they penetrate the cavity of the colony (into which the oogonia have now pushed), and there coming in contact with the oogonia, they

* It will not do violence to any laws of classification, based upon the general theory of evolution, to propose that *Volvox*, *Eudorina*,

bury themselves in the hyaline envelope, and finally penetrate and become fused into the oosphere (*b*, Fig. 164). A thick wall now forms upon the fertilized oosphere, and it becomes transformed into an oospore. Thus we have in these plants the transformation of an individual of the colony into an oogonium and oosphere, and the subsequent fertilization of the latter by spermatozoids, which are themselves fractional parts of other members of the colony.

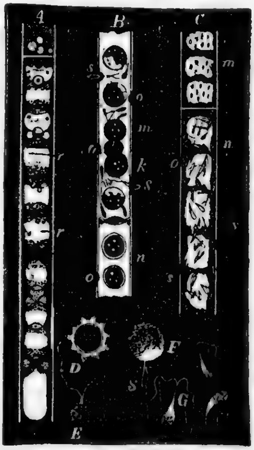


Fig. 165.—*Sphæroplea annulina.* *A*, ordinary filament; *r*, chlorophyll masses. *B*, filament consisting of oogonia, the contents breaking up into oospheres; *o*, *o*, openings for entrance of spermatozoids; *s*, *s*, spermatozoids entering the oogonia; *m* and *k*, oospheres at the instant of fertilization; *n*, fertilized oospheres, now enclosed in a thin cell-wall. *C*, filament consisting of antheridia; *s*, *s*, the escaping spermatozoids, issuing through the openings *o o*. *D*, an oospore with its thick coats of cellulose. *E*, zoospore (vegetative zoogonidium). *F*, oosphere in the act of being fertilized by a spermatozoid, *s*. *G*, spermatozoids.—After Œrsted.

326.—The relationship of the lower Oophytes with the lower Zygophytes, as indicated by *Volvox* and *Pandorina*, is further shown by the position of *Sphæroplea*, an undoubted relative of the *Confervaceæ* (*Cladophora*, etc.). *Sphæroplea* is a free, unbranched, filamentous alga, composed of long cells joined end to end (*A*, Fig. 165). It produces oospheres in some of its filaments, each cell producing several (*B*, Fig. 165). While these are forming in one set of filaments, in another the protoplasm becomes broken up into a multitude of elongated, bi-ciliate spermatozoids (*C* and *G*, Fig. 165); these escape through lateral openings in the cells, which are formed by the absorption of a part of the wall, and then swimming through the water they find their way to corresponding openings in the walls of the

---

and their allies in the Oophyta, and *Pandorina* and its allies in the Zygophyta, be placed in a common class Zoosporeæ. This class would thus have two branches, one in the division Zygophyta, and the other in the Oophyta. Such an arrangement would indicate the evident relationship of the plants under consideration better than any yet proposed.

cells, which contain the oospheres; upon coming in contact with an oosphere they bury themselves in its substance, after which the oosphere secretes a thick wall, and thus becomes an oospore (*D*, Fig. 165). In germination (which takes place after a period of rest) the protoplasmic contents of the oospore become broken up into a large number of bi-ciliated zoospores having nearly the shape and general appearance of the spermatozoids; these, after swimming about for a time, become gradually elongated into narrowly fusiform filaments, which are the young *Sphæroplea* individuals; by growth these take on the form and size of the adult individuals.

§ II. Class Œdogonieæ.

327.—The plants constituting this well-marked class are composed of articulated, simple, or branched filaments, which are attached to sticks, stones, earth, or other objects by root-like projections of the basal cells. The chlorophyll in the cells is always dense and uniform. They inhabit ponds and slow streams, and form green masses, which fringe the sticks and other objects in the water.

328.—The Œdogonieæ are interesting for the well-marked examples they afford of the intercalary growth of cells. It is commonly the case that in any filament at one or two points there may be seen near one end of a cell a number of transverse parallel lines, which in profile have the appearance of as many caps slipped into one another (*C*, Fig. 10, page 22); these are the results of several extensions of the filaments by intercalary growth. The process is as follows: in a cell, a little below its upper wall, a growth inward from the surface of the wall takes place in such a way as to form a cylindrical ring (*A*, *f*, Fig. 10); after a time the cell-wall splits circularly from the outside to the centre of the circular cylinder (*f*), and the two parts of the cell then retreat from each other, united only by the straightened out cylinder (*B*, *z*, Fig. 10); this new part elongates and the process is repeated, finally giving rise to the series of caps first mentioned (*C*, *c*, Fig. 10), and, in conjunction with cell-division, resulting in a considerable elongation of the filaments.

329.—The asexual reproduction of Œdogonieæ is as curious as the growth of its cells, just described. During the early and active growth of the plants the protoplasmic contents of certain cells in a filament become detached from their walls, and upon the splitting of the latter the now rounded protoplasm escapes as a large zoospore (Fig. 166, *A* and *B*); it is oval in shape, and provided with a crown of cilia about its smaller hyaline end, by means of which it swims rapidly hither and thither in the water (Fig. 166, *C*). After a time it comes to rest, clothes itself with a cell-wall, and sends out from its smaller end root-like prolongations (Fig. 166, *D*), which attach it to some object; it now elongates, and at length forms partitions, taking on eventually the form of the adult filament. It sometimes happens that before the new plant resulting from the growth of a zoospore has formed its first partition, the protoplasm separates from its wall and again abandons it, to be for a time a zoospore (Fig. 166, *E*). This method of formation of zoospores is what Braun called Rejuvenescence. (See p. 42.)

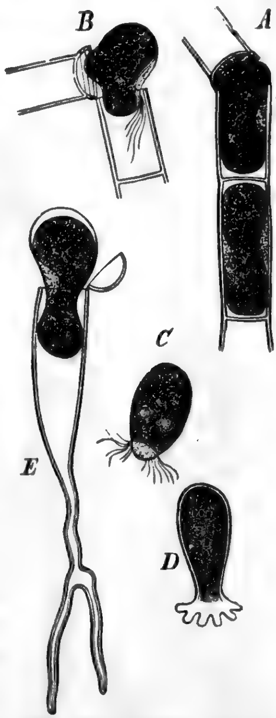


Fig. 166. — Asexual reproduction of *Œdogonium*. *A*, fracture of a filament and escape of the protoplasm of the broken cell; the protoplasm in the whole cell below is seen to be somewhat withdrawn from the cell-wall, preparatory to escaping. *B*, escape of protoplasm and formation of a zoospore; the hyaline portion of the latter is seen to be lateral. *C*, a ciliated and swimming zoospore, the hyaline portion now terminal. *D*, zoospore at rest, and sending out root-like prolongations from the hyaline end. *E*, a young plant composed of only one cell, with its protoplasm escaping. × 350.—After Pringsheim.

330.—The sexual reproduction of the plants of this class is in many respects closely allied to that of *Sphæroplea*. The female organs are in all cases developed in essentially the same way, but the male organs present a considerable diversity. The female organ

consists of a rounded oosphere situated within a cavity—the oogonium; it is developed from one of the cells (sometimes two) of the filament by a condensing and rounding off of the protoplasmic contents; when the oosphere is fully formed, an opening is formed in the oogonium-wall for the ingress of the spermatozoids (*A* and *B*, Fig. 167). One or more spermatozoids are produced in each of certain small cells which are formed from the large ones by a process of simple fission; in shape they resemble the zoospores mentioned above—that is, they are oval and provided with a crown of vibratile cilia on their smaller extremity (*D*, *z*, *z*, Fig. 167). Upon escaping into the water, which is rendered possible by a splitting of the wall of the mother-cell, they swim about vigorously, and eventually make their way through the opening in the oogonium, and then bury

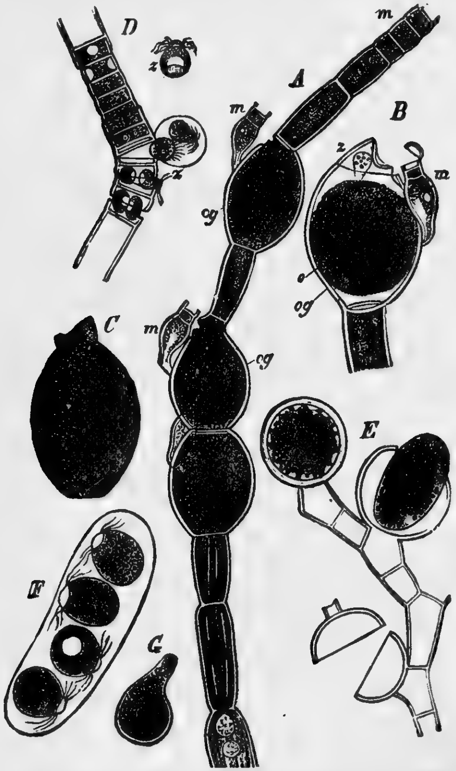


Fig. 167.—*A*, middle part of a sexual filament of *Œdogonium ciliatum* (*Androgynia* of Wood), with male cells above at *m*; *og*, oogonia (fertilized); *m*, dwarf male plants attached to the side of the oogonia, the spermatozoids already discharged. × 250. *B*, oogonium, *og*, at the moment of fertilization; *o*, the oosphere; *s*, the spermatozoid forcing its way into the oosphere; *m*, the dwarf male plant. *C*, ripe oospore. *D*, *Œdogonium gemelliparum* (*Pringsheimia* of Wood), part of the male filament, with spermatozoids, *s*, issuing from the cells. *E*, part of a branch of *Bulbochæte intermedia*, with oogonia, the uppermost containing an oospore, the middle one with an oospore escaping, the lower empty. *F*, four zoospores resulting from an oospore of *Bulbochæte*. *G*, zoospore come to rest and germinating.—After Pringsheim.

themselves in the substance of the oosphere (*B*, *z*, Fig. 167). After fertilization the oosphere becomes covered with a thick and colored (brown or red) coat, and it then becomes an oospore (*C*, Fig. 167).

331.—In certain cases the cells which produce the spermatozoids occur on the same filaments which produce oogonia also; this is the *monœcious type*. In other cases one of the ordinary cells of the filament which bears oogonia becomes divided by simple fission into two or more cells; the protoplasm in each of these new cells condenses into an ovate mass, which by a rupture of the cell-wall is set free as a motile body resembling a small zoospore, and, like it, provided with a crown of vibrating cilia; this is the *androspore.* After swimming about for some time, it comes to rest upon, or near to, an oogonium, and attaches itself by root-like projections, exactly as in the case of the growth of true zoospores; the result of the growth of the androspore is the production of a miniature plant composed of three or four cells (*A*, *m*, *m*, and *B*, *m*, Fig. 167). The upper cells of these little plants develop spermatozoids, and hence the plants are called dwarf males. This is the so-called *gynandrous type* (*A* and *B*, Fig. 167). In a third class of cases, the ordinary plant filaments are of two kinds, the one producing spermatozoids only, and the other only oogonia; this is the *diœcious type* (*D*, Fig. 167).

332.—After a period of rest the oospore germinates by rupturing its thick coat, and permitting the escape of the contents, enclosed in a thin envelope; by this time the protoplasm has divided into four portions, which take on an oval form, and develop a crown of cilia (*F*, Fig. 167). They soon escape from the investing membrane, and after a brief period of activity grow into an ordinary filament in exactly the same manner as the zoospores.

(*a*) It will be unnecessary in this place to fully discuss the arrangement of the genera belonging to this class; they probably may be all brought within the limits of one order coextensive with the class. Wood has separated* two sub-families (= sub-orders), which differ in

---

* "A Contribution to the History of the Fresh-water Algæ of the United States," by H. C. Wood, 1872.

the filaments in the one case (*Bulbochæte*) being branched and terminated with setæ, while in the other case (*Œdogonium* and its allies) the filaments are not branched, and are destitute of true setæ.

(*b*) The old genus *Œdogonium* is divided by Wood into three new genera, as follows:

Monœcious: antheridia and oogonia upon the same individual—*Œdogonium.*

Diœcious: antheridia and oogonia arising upon distinct individuals—*Pringsheimia.*

Gynandrous: antheridia upon dwarf plants, growing attached to the female plant—*Androgynia.*

Wolle records thirteen species of the first, thirteen of the second, and twenty-six of the third of the foregoing divisions in the United States. He does not, however, consider these divisions as having generic rank. ("Fresh-water Algæ of the United States," Vol. I. p. 66.)

(*c*) The genus *Bulbochæte* includes gynandrous species, of which there are sixteen in the United States.

§ III. Class Cœloblasteæ.

333.—In the plants of this class the protoplasm is continuous throughout the vegetative organs of the plant, and is not divided into cells. Only the reproductive organs are separated by partitions. They may hence be spoken of as unicellular, although they often attain a considerable length and are frequently much branched.

The other characters of the group will be best understood from a study of some of the plants included in it. Many of them are chlorophyll-bearing plants, living in brooks and streams, while others are destitute of chlorophyll, and are saprophytes, living upon decaying animal or vegetable matter, or are parasites, living upon the living tissues of the higher plants.

334.—The genus *Vaucheria* may be taken as a representative of the chlorophyll-bearing members of this class. It is a filamentous alga growing in water or on damp earth, and forming dark green tufts. Each plant consists of long, branching, thick-walled tubes, which have a rather large diameter; they are attached to the earth, or to sticks or

other objects, by root-like processes (*w*, Fig. 168). The protoplasmic contents of the tubes, which are destitute of a nucleus, consist of a thick green layer upon the inner surface of the wall, leaving the centre of the tubes open for the more watery portions.

335.—The asexual reproduction of *Vaucheria* presents some considerable variations; it consists essentially of a spontaneous separation of a portion of the protoplasm of the parent plant. In some species this takes place by the sepa-

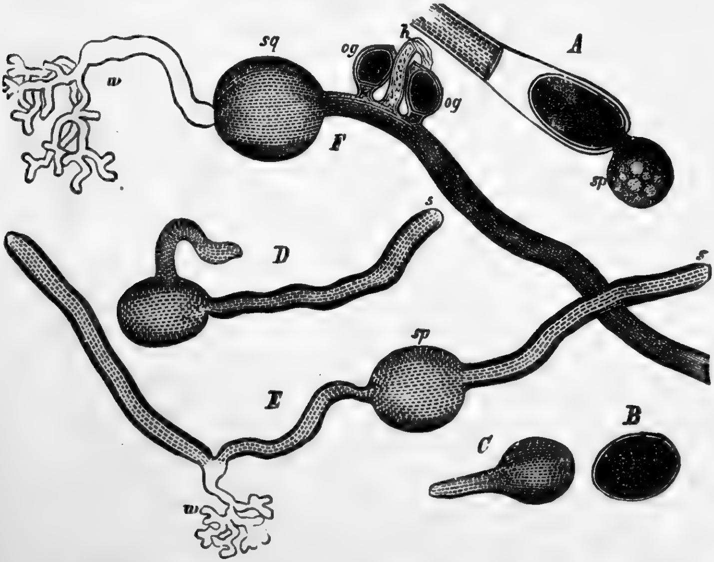


Fig. 168.—*Vaucheria sessilis.* *A*, end of a branch, with escape of a zoospore, *sp*. *B*, zoospore in its resting stage, after the disappearance of its cilia. *C*, the same, germinating. *D*, the same, further advanced. *E*, much later stage of germination; *sp*, the zoospore; *w* the root-like processes (rhizoids). *F*, fertile plant; *og*, *og*, oogonia fertilized; *h*, an old antheridium. × 30.—After Sachs.

ration of swollen lateral branches, which then send out filaments; in other species the protoplasm in the swollen lateral branch becomes separated from that in the general cavity of the plant by a septum, and it afterward condenses into a rounded mass and acquires a wall of its own; it is set free by the decomposition of the old surrounding wall, and it germinates by sending out one or two tubes, which grow

directly into new plants. In still other species the spore forms as in the last case, but there is a dehiscence of the surrounding wall which permits the spore to slip out; it begins to germinate soon. In some species, instead of forming a spore, the naked protoplasm in the swollen branches, after condensing somewhat, escapes into the water through a fissure in the cell-wall, and becomes a zoospore (*A*, Fig. 168); it is covered throughout its whole surface with delicate vibratile cilia, by means of which it moves through the water (Fig. 169). After a short period of activity the zoospores come to rest, their cilia disappear, and a wall of cellulose is formed (*B*, Fig. 168); in this condition (the *zoogonidium*) they remain for some hours, when they begin to germinate by sending out one or two tubes (*C*, *D*, Fig. 168); the root-like organs grow either directly from the zoogonidium (*F*, Fig. 168), or from one of the tubes (*E*, Fig. 168).

Fig. 169.—Section at right angles to the surface of a zoospore of *Vaucheria sessilis*. *a*, ectoplasm bearing the cilia; *b*, endoplasm. × 600.—Osmic acid preparation, after Strasburger.

336.—Sexual reproduction takes place in lateral branches also. Both antheridia and oogonia develop as lateral protuberances upon the main stem (*og*, *og*, *h*, Fig. 168). They originate as diverticula of the principal cavity (*A*, *og*, *h*, Fig. 170); these develop on the one hand into male organs, and on the other into female organs. The male organ is long and rather narrow, and soon much curved (*B*, *a*, Fig. 170); its upper portion becomes cut off by a partition, and in it very small bi-ciliate spermatozoids (*D*, Fig. 170) are developed in great numbers. The female organ is short and ovoid in outline, and usually stands near the male organs. In it a partition forms near its point of union with the main stem; the upper portion becomes an oogonium, and its protoplasm condenses into a rounded body, the oosphere (*C* and *E*, Fig. 170); at this time the wall of the oogonium opens, and permits the entrance of the spermatozoids which were set free by the rupture of the antheridium-wall. Upon coming into contact with the oosphere the spermatozoids mingle with it and disappear; the

oosphere immediately begins to secrete a wall of cellulose about itself, and it thus becomes an oospore (*F*, Fig. 170). According to Pringsheim, the oospore remains for three months in a resting state before germinating; in the latter process the outer coat of the spore splits, and through the opening a tube grows out which eventually assumes the form and dimensions of the full-grown plant.

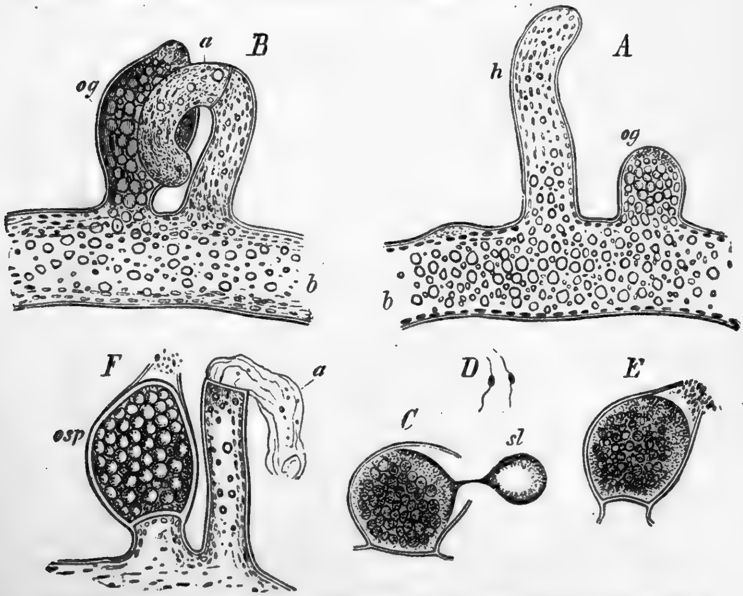


Fig. 170.—Sexual organs of *Vaucheria sessilis*. *A*, beginning of the formation of the oogonium (*og*) and antheridium (*h*) upon the branch *b*. *B*, later stage of the same, the antheridium (*a*) now separated from the main branch (*b*) by a transverse partition. *C*, an open oogonium expelling a drop of mucilage, *sl*. *D*, spermatozoids. *E*, spermatozoids collected at the mouth of the oogonium. *F*, the antheridium, *a*, collapsed after the escape of the spermatozoids; *osp*, the oospore. × about 100, except *D*, which is much more.—*C*, *D*, after Pringsheim, the others after Sachs.

(*a*) The formation of zoospores begins in the night, they escape in the morning, and the night following they germinate.

(*b*) The formation of sexual organs begins in the evening, and is completed the next morning; fertilization takes place during the day (from 10 A.M. to 4 P.M.).

(*c*) Good specimens of *Vaucheria* may be found clothing the boggy ground about many springs. The bright green mats may be transferred to the aquarium for the study of zoospores; but for the sexual organs the dingy and dirty looking specimens must be collected.

(*d*) The genus *Vaucheria* may be taken as the type of a group, the *Vaucheriaceæ*, but whether it is entitled to rank as an order instead of a family cannot be decided in this place. Allied to *Vaucheria* are *Caulerpa*, *Halimeda*, etc., but their exact position is as yet problematical.

(*e*) Thirteen species of *Vaucheria* occur in the fresh waters of the United States, one of the most common being *V. sessilis*, which occurs everywhere in brooks and springs.

(*f*) *Caulerpites cactoides* is the oldest known fossil species of this class. It occurs in the Silurian: other species have been detected in the Devonian and Tertiary. *Caulerpa* extends from the Tertiary to the present.

337.—Order Saprolegniaceæ. The plants of this order are saprophytes or parasites, more frequently the latter; they are colorless, and generally are to be found in the water or in connection with moist tissues. The plant-body is greatly elongated and branched, and all its vegetative portion is continuous—*i.e.*, unicellular; the reproductive portions only are separated from the rest of the plant-body by partitions.

338.—The reproduction is very much the same as in *Vaucheria*, and, as in that genus, is of two kinds—asexual and sexual. The asexual reproduction may be briefly described as follows: the protoplasm in the end of a branch becomes somewhat condensed, a septum forms, cutting off this portion from the remainder of the filament, and the whole of its contents becomes converted by internal cell-division into zoospores provided with one or two cilia (Fig. 171, 1). These soon escape from a fissure in the wall and are active for a few minutes (3–4), after which they come to rest and their cilia disappear (2 and 3, Fig. 171). In one or two hours they germinate by sending out a filament (4, Fig. 171), from which a new plant is quickly produced.*

339.—The sexual organs bear a close resemblance to those of *Vaucheria*. The oogonia are spherical, or nearly so (in most of the species), and contain from two to many oospheres, which are fertilized by means of antheridia, which usually develop as lateral branches just below the oogonia. In

---

* The student is referred to an article, "Observations on Several Forms of Saprolegnieæ," by F. B. Hine, in *American Quarterly Microscopical Journal*, 1878, p. 18, from which some of the above facts are taken, and the accompanying figures adapted.

some species the antheridia and oogonia are upon the same plants, and in such cases the fertilization takes place by the

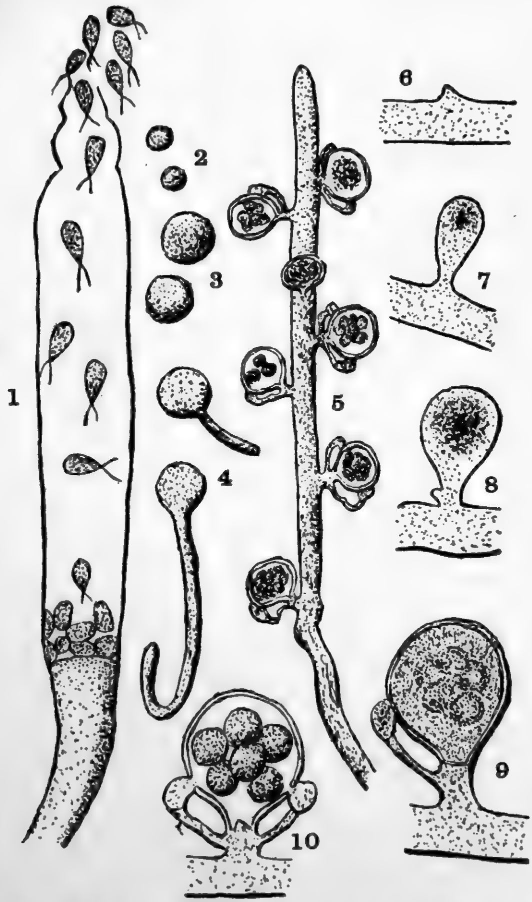


Fig. 171.—1, end of filament of *Saprolegnia*, with zoospores (swarm-spores) escaping; 2, zoospores of the same at rest; 3, the same more enlarged; 4, the same, germinating; 5, a portion of a filament of *Achlya*, bearing sexual organs, × 120; 6, first stage in the development of sexual organs of *Achlya*; 7, 8, 9, succeeding stages; 10, sexual organs of 5, more enlarged, showing the antheridia, and the nearly ripe oogonium, with its contained oospores.—Adapted from Hine.

direct contact of the antheridium and the passage of its contents into the oogonium by means of a tubular process

from the former ; in other species the plants are diœcious, and in them the antheridia produce motile spermatozoids, by means of which the fertilization is effected. After fertilization each oosphere becomes covered with a wall of cellulose and is thus transformed into an oospore.

340.—The development of the sexual organs of *Achlya*, one of the genera of this order, is shown in Fig. 171, 6 to 10 ; at first there is a small pullulation upon the side of a filament, as at 6 ; this soon extends into a bag-like projection (7), which is readily seen to be a young oogonium ; it continues to enlarge, while its protoplasm becomes more dense, and at its narrower part a second pullulation forms (frequently two), as shown at 8 ; when the larger part has enlarged somewhat more and become rounded, a partition separates it from the remainder of the filament, and from the young antheridium, as shown at 9 ; the protoplasm in the oogonium forms several round masses—the oospheres—and by this time the terminal portion of the antheridium is cut off by a partition. In the monœcious species a tube is formed by the closely applied antheridium, which penetrates into the oogonium through openings in it formed by the absorption of portions of its wall and comes in contact with one of the oospheres (Fig. 172).

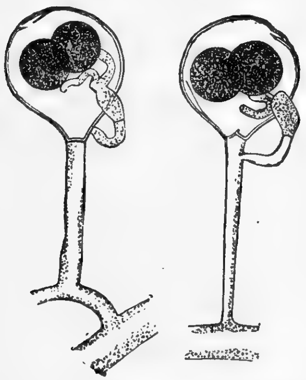


Fig. 172.—Fertilization of the oospheres in *Achlya racemosa*. Each oogonium contains two oospheres. Magnified.—After Cornu.

341.—In some cases, instead of the oogonia developing in the way described above, they are formed in the terminal part of a filament by one or more partitions arising in it ; such oogonia are cylindrical or barrel-shaped, and sometimes several of them stand upon one another. The antheridia in the species which have such oogonia are developed from below the partition which cuts off the oogonium, and when there are several superimposed oogonia it actually happens

that the antheridia which fertilize one oogonium grow out of the oogonium lying immediately beneath.* In this case it appears that the terminal oogonium is formed first, and that the antheridia, in each case, grow out from what is yet a part of the whole filament, and that it is only subsequently to the formation of antheridia that an oogonium is formed out of that part of the filament out of which they grew. In the accompanying diagram (Fig. 173) the oogonium *a* is fertilized by antheridia which grew out of that portion of the filament which subsequently became cut off as oogonium *b*, which in turn is fertilized by antheridia from below it, and so on to *d*, which receives its antheridia from what still remains as part of the filament. Each oogonium is seen to be younger than the one above it—in other words, the oogonia are developed from the top of the filament downward.

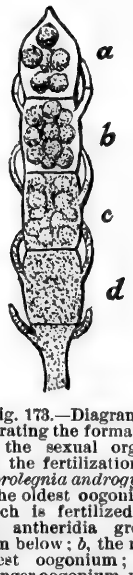


Fig. 173.—Diagram illustrating the formation of the sexual organs and the fertilization of *Saprolegnia androgyna*. *a*, the oldest oogonium, which is fertilized by the antheridia grown from below; *b*, the next oldest oogonium; *c*, younger oogonium, with the oospheres not yet fully formed; *d*, youngest oogonium; the latter will be fertilized by the antheridia which grow out from the upper end of the filament below.

The oospores of Saprolegniaceæ possess, when mature, a thick integument, which is double—that is, formed of an outer thicker coat (epispore) and an inner thinner one (endospore). After a considerable period of repose the oospores germinate by sending out a tube.†

The Saprolegniaceæ have been but little studied in this country, although they may be readily obtained. They grow quickly upon dead fishes, crayfishes, flies, etc., when placed in tanks of water, and may often be seen attached parasitically to young living fishes in aquaria. They are often so abundant in the breeding-houses of fishes as to cause great losses. In some of the rivers in England dur-

*** The student should consult an article on "Two New Species of Saprolegnieæ," etc., in *Qr. Jour. Mic. Science*, 1867, p. 121, in which figures and a description of such a form as that above referred to are given.**

† See De Bary's "Morphologie und Physiologie der Pilze," etc., 1866, p. 155, for an account of the sexual reproduction of Saprolegniaceæ,

ing the year 1878, and for a year or two previous to that date, large numbers of salmon and other kinds of fish were destroyed by one of the common species, *Saprolegnia ferax.**

342.—Order Peronosporeæ. The plants of this order live parasitically in the interior of higher plants. They are composed of long branching tubes, whose cavities are continuous throughout. They grow between the cells of their hosts, and draw nourishment from them by means of pecu-

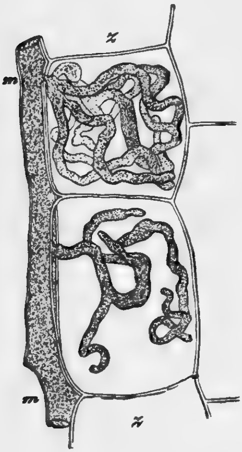


FIG. 174.

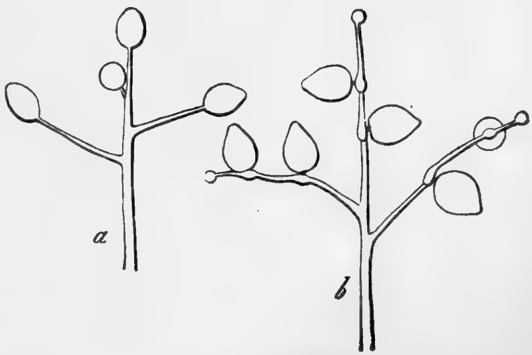


FIG. 175.

Fig. 174.—A vegetative hypha, *m*, *m*, of *Peronospora calotheca* from the tissue of *Asperula sativa.* The two cells between *z z* are filled with the long branching haustoria from the hypha *m*, *m*. × 390.—After De Bary.

Fig. 175.—Conidia-bearing hyphæ of *Peronospora infestans*. *a*, formation of the first conidia upon the ends of slender pedicels; *b*, the formation of the second and third conidia; the pedicel is proliferous from the base of each conidium after it is formed, and thus the conidia, which are actually terminal, come to appear lateral. × 200.—After De Bary.

liarly formed lateral branches (*haustoria*), which thrust themselves through their walls (Fig. 174, and Fig. 176, *A*, *h*). The vegetative growth is entirely within the host, and also

---

and a translation in "Grevillea," Vol. I., p. 117. See also Pringsheim's "Jahrbucher für Wissenschaftliche Botanik," Vol. IX., p. 289, and Max Cornu, in "Annales des Sciences Naturelles," 5e ser., tom. XV.

* See a description by W. G. Smith in "Grevillea," Vol. VI., 1878, p. 152.

the sexual organs; the asexual reproductive organs, on the contrary, are on the surface of the host.

343.—The asexual reproduction takes place in the genus

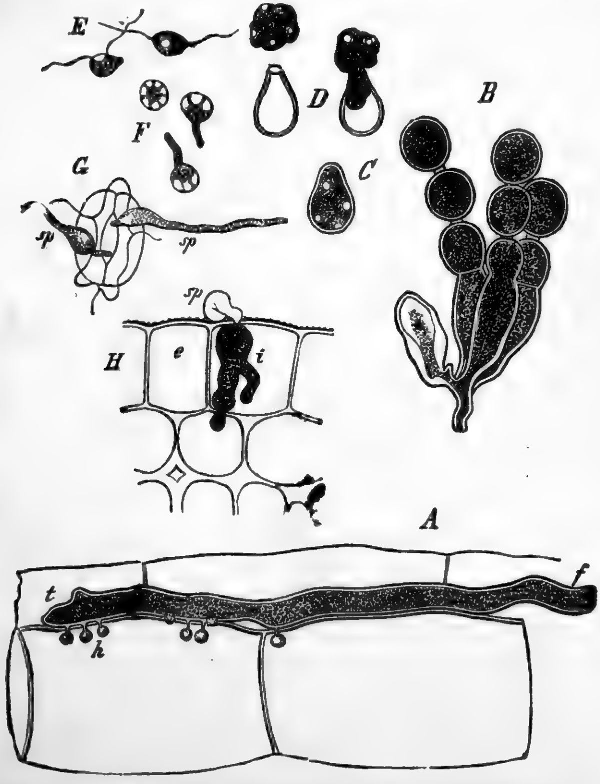


Fig. 176.—*Cystopus candidus.* *A*, branch of mycelium, *f*, growing at the apex, *t*, and giving off haustoria, *h*, into the cells of the pith of *Lepidium sativum.* *B*, conidia-bearing portions of the mycelium, with conidia in rows. *C*, a conidium with its protoplasm divided. *D*, contents of conidia escaping as swarm-spores (zoospores). *E*, swarm-spores (zoospores), with cilia. *F*, germinating swarm-spores. *G*, two swarm-spores, *sp*, germinating on a stoma and penetrating it. *H*, a swarm-spore, *sp*, of the potato disease (*Peronospora infestans*) penetrating the epidermis of the potato stem; *e*, *i*, epidermis cells. × 400.—After De Bary.

Peronospora by the mycelium inside the host producing branches, which protrude through the stomata into the air; here their tips become enlarged, and finally separated by partitions from the remaining parts of the hyphæ, thus forming

the conidia (Fig. 175). In the different species there are considerable variations in the size and shape of the conidia, and the mode of branching of the conidial hyphæ, and upon these many specific characters are based.

344.—In the genus *Cystopus* the formation of conidia is slightly different. The conidial hyphæ multiply greatly at certain points beneath the epidermis of the host, and there produce conidia by successive constrictions (*B*, Fig. 176). The conidia remain in loose connection, and form moniliform rows, in which the uppermost conidium is the oldest; sometimes six or more conidia may be seen attached to each other in this way, but generally the upper ones soon fall away. When the epidermis of the host ruptures, the conidia appear as a powdery mass, which may be blown away by the feeblest movement of the air.

Fig. 177.—Germination of the conidia of *Peronospora infestans*. *a*, conidium after lying for some time in water, the contents divided; *b*, the rupture of the conidium and the escape of the parts as swarm-spores (zoospores); *c*, swarm-spores, with cilia; *d*, swarm-spores after coming to rest, in various stages of germination. × 390.—After De Bary.

345.—The germination of conidia presents two modes: in some species of the genus *Peronospora* the contents of the conidium, when placed under the proper conditions of moisture and temperature, become transformed into many bi-ciliate swarm-spores (*a*, *b*, and *c*, Fig. 177). These are active for a time, after which they come to rest, their cilia disappear, and a germinating tube is sent out from each (*d*, Fig. 177), which, if properly situated, enters a stoma, and in the interior of its host gives rise to a system of vegetating hyphæ; in other cases it perforates the epidermis cell-walls and thus passes into the interior of its host (*H*, Fig. 176). In other species of *Peronospora* the conidium does not break up into swarm-spores, but gives rise directly to a germinating filament. In all the species of the genus *Cystopus*, the conidia first give rise to swarm-spores (*C, D, E, F, G*, Fig. 176), in the manner described above for *Peronospora.*

346.—In the sexual reproduction,* which, as above stated, always takes place in the intercellular spaces of the host, lateral branches of two kinds arise upon the hyphæ; those of the one kind, the young oogonia, become greatly thickened

Fig. 178.—The sexual organs and fertilization of *Peronospora Alsinearum*. *a*, youngest stage; *o*, young oogonium; *n*, young antheridium; *b*, the same somewhat later; the antheridium is beginning to thrust its beak-like process (fertilizing tube) into the oogonium; *c*, the same at a still later stage—the fertilizing tube has reached the oosphere. × 350.—After De Bary.

in diameter, and finally assume a globular shape; their highly granular protoplasm becomes condensed, and finally separated from that of the remainder of the filament by a transverse septum at the base of each oogonium (*a*, Fig. 178). The other branches, the young antheridia, which arise upon the same filaments as the oogonia and near to them, or upon other filaments which are in proximity to the oogonia-bearing ones, become elongated and club-shaped; their protoplasm (also granular) becomes condensed in their upper portions, which are soon separated from the rest of the filament by a transverse partition in each case (*a*, Fig. 178). At this stage the antheridia become applied to the oogonia, and in each of the latter the protoplasm has still further condensed and

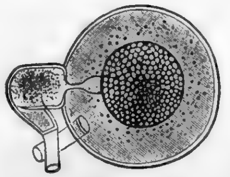


Fig 179.—Oogonium of *Peronospora*, with its contained oosphere; at the left is the antheridium, which has penetrated the oogonium and brought its fertilizing tube into contact with the oosphere. Much magnified.—After De Bary.

* Consult De Bary's "Morphologie und Physiologie der Pilze," etc., pp. 158–159, a translation of which appeared in "Grevillea," 1873, p. 150.

rounded into an oosphere. Each antheridium now develops a tubular beak-like process, which penetrates the oogonium (*b*, Fig. 178), and finally reaches the oospore (*c*, Fig. 178, and Fig. 179). It appears that the contents of the an-

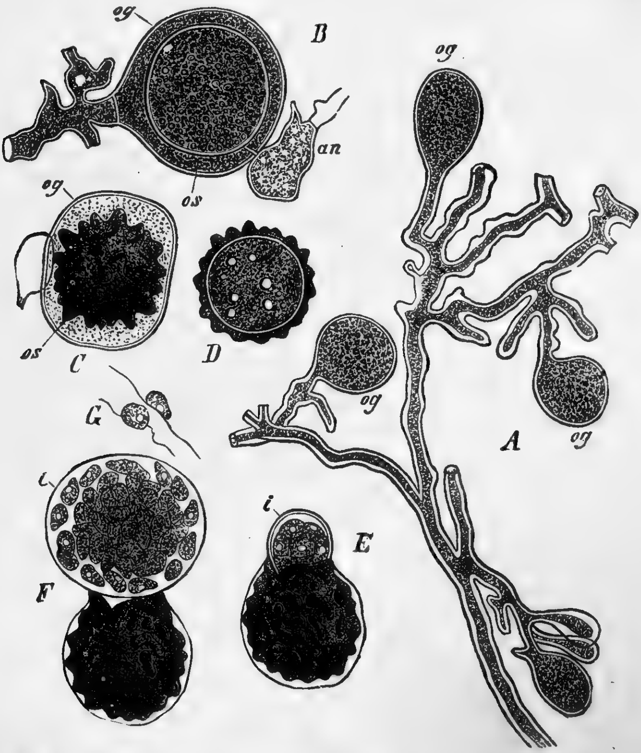


Fig. 180.—*Cystopus candidus*. *A*, mycelium, with young oogonia, *og*. *B*, oogonium, *og*; *os*, oospore; *an*, antheridium. *C*, mature oogonium, *og*, with oospore, *os*; at the left is the remnant of the antheridium. *D*, mature oospore seen in section. *E*, beginning of germination of oospore, the endospore *i* with its contents escaping through a rent in the epispore (or exospore). *F*, the endospore *i* filled with swarm-spores (zoospores) resting on the empty epispore. *G*, swarm-spores (zoospores), each with two cilia. × 400.—After De Bary.

theridium pass into the oosphere, as in a short time the former is found to be empty, while the latter becomes enveloped in a cell-wall, and thus becomes an oospore. In the process of fertilization there are no spermatozoids, and the

process is comparable to that which takes place among the monœcious Saprolegniaceæ. The wall of the oospore becomes differentiated into two or more layers (as, in fact, is usual in resting spores), the outer of which (the *epispore*) is thick, hard, rough, and dark colored, while the inner (the *endospore*) is thin and transparent (*C, D, E, F,* Fig. 180).

347.—In their sexual reproduction the species of the genus *Cystopus* agree with those of *Peronospora* above described. The various stages are shown in Fig. 180.

348.—The germination of the oospores takes place in some species of the genus *Peronospora* by the formation of a germinating tube, which soon gives rise to a mycelium. In *Cystopus,* however, the oospore swells, and by the bursting of the epispore the endospore escapes as a loose bladder surrounding the protoplasm, which has by this time become divided into a large number of naked masses of protoplasm (*E, F,* Fig. 180); by the bursting of the surrounding membrane, these bodies are set free as bi-ciliate swarm-spores (*G,* Fig. 180), which, after a short period of activity, come to rest, and germinate in exactly the same way as those derived from the conidia. In some species of *Peronospora* it appears that swarm-spores are developed as in *Cystopus,* and it appears from the observations of W. G. Smith, that in the potato fungus (*Peronospora infestans*) some of the oospores produce swarm-spores, while others send out a germinating tube.*

349.—But little is known regarding the time, as well as the mode of germination of the oospores, but from those observed it is probable that it takes place after a period of rest extending from autumn to spring. This is known to be the case in some species of *Cystopus,* in which the oospores pass the winter in the rotting tissues of its hosts.

---

* See a paper "On the Germination of the Resting Spores of Peronospora Infestans," by Worthington G. Smith, in *Gardeners' Chronicle,* July, 1876, and reprinted in "Grevillea," 1876, p. 18. He found that the oospores which germinated first produced swarm-spores like those of *Cystopus,* while the later ones "protruded a thick and generally jointed thread." In his account figures of both modes are given.

(*a*) The plants of this order are easily obtained, and so far as their structure is concerned, are easily studied. Their development is, however, much more difficult to follow, and in some species it has thus far baffled the most skilled botanists. The two genera *Peronospora* and *Cystopus* are distinguished by their conidia, which in the first are terminal and single upon branches of the aerial hyphæ (Fig. 175), while in the second they are in moniliform rows upon hyphæ which burst through the epidermis of the host (*B*, Fig. 176).

(*b*) Several species of *Peronospora* are very easily obtained. *P. viticola*, the American grape mildew, is common on the leaves and young shoots of the grape; from it may be obtained in midsummer an abundance of conidia and conidial hyphæ, and in autumn (October) the oospores may be found in abundance in the dried and shrivelled parts of the affected leaves.* *P. parasitica* is common in spring and early summer, on Cruciferæ, especially on *Lepidium*, *Capsella*, *Draba*, etc., frequently clothing the leaves with a white, frost-like down. *P. infestans*, the potato fungus, is common in many parts of the country on the leaves and stems of the potato, sometimes causing great injury by destroying the leaves, stems, and even the tubers. Other species occur on *Eupatorium*, *Bidens*, *Ambrosia*, *Impatiens*, *Potentilla*, *Anemone*, etc.

(*c*) The species of *Cystopus* which are most common are *C. candidus*, which may be found in the spring and summer as white, blister-like blotches on the leaves of *Capsella* and other Cruciferæ; and *C. Bliti* common on *Portulaca oleracea* and species of *Amarantus* in summer and autumn; the latter is an excellent species to study, as its oospores are very easily found, especially in the stems of *Portulaca*.

(*d*) In preparing specimens for the study of the sexual organs, small portions of the tissues containing them should be boiled for a minute or so in a solution of potash, and then, while the preparation is hot, a considerable quantity of acetic acid should be added; the effervescence which follows separates the softened tissues so that but little difficulty is experienced in isolating large portions of the mycelium with oogonia and antheridia. It frequently happens that the parts are rendered more distinct by the addition of iodine to the specimen after mounting

§ IV. Class Fucaceæ.

350.—The plants of this class, composed of marine species, present, in most cases, a development of the plant-body which is unusually perfect for the Thallophytes. In many

* For the best account of this fungus see a paper "On the American Grape-vine Mildew," by Professor W. G. Farlow, in *Bulletin of the Bussey Institution*, Vol. I., p. 415. Several other species are also briefly described.

cases there is a differentiation of the thallus into parts which have a considerable resemblance to roots, stems, and leaves; and in size they approach, and, in some cases, equal or exceed the larger Phanerogams. Their tissues, too, show a much higher degree of differentiation than is common in Thallophytes; the cells are arranged in cell-masses, and these are differentiated into several varieties of parenchyma, approaching, in some instances, to the condition which prevails in the Bryophytes; the outer tissues are composed of small and closely crowded cells, which form a dense, and, in some cases, a hard mass; the interior tissues are generally looser, and are for the most part composed of elongated cells so joined as to leave large intercellular spaces.

351.—With the foregoing there is found in the higher genera a marked differentiation of portions of the plant-body into general reproductive organs, analogous to the floral branches of higher plants. The sexual organs are found upon modified branches, which differ more or less in shape and appearance from the ordinary ones. This differentiation into vegetative and reproductive parts is an important and significant feature in the plant-body, indicating a decided advance over all the previous groups of Thallophytes.

In their greater duration many of the Fucaceæ are in marked contrast to other Thallophytes, which are generally short-lived. They are, for the most part, of considerable size, rivalling, in some cases, even the larger Phanerogams. They grow principally between and a little beyond the tide-marks, and furnish the great bulk of the shore vegetation.

352.—The reproduction of the higher Fucaceæ is sexual only; but in some algæ which appear to be nearly allied (Phæosporeæ) asexual zoospores are known. In *Fucus* the sexual organs are found in the thickened ends of the lateral branches of the thallus (*A*, Fig. 181). They occur on the walls of hollows termed *conceptacles*, which are spherical, with a small opening at the top (*B*, Fig. 181). The conceptacles are at first portions of the general surface, which afterward become depressions which are walled in and overgrown by the surrounding tissues; they are thus to

be still regarded as portions of the general surface, and the cells which form the inner surface of the conceptacles constitute a continuation of the epidermal tissue of the thallus.

353.—The walls of the conceptacles are clothed with pointed hairs, which in some species project through the

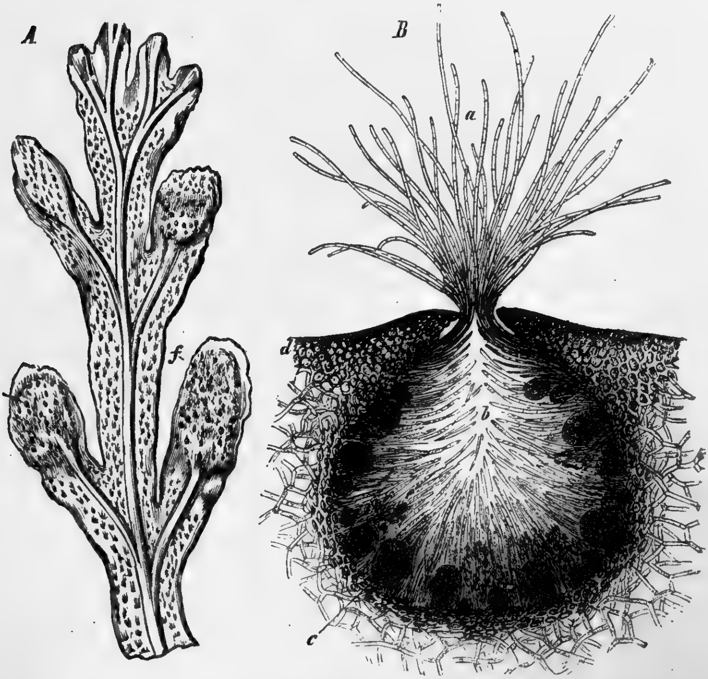


Fig. 181.—*Fucus platycarpus.* *A*, end of a portion of thallus; *f*, *f*, conceptacles in fertile branchlets. *B*, vertical section through a conceptacle; *a*, hairs projecting from the mouth; *b*, cavity of conceptacle nearly filled with hairs; *c*, oogonia; *e*, antheridia; *d*, epidermal tissue of thallus.—After Thuret.

opening, and among these are found the sexual organs, which are themselves, as Sachs has pointed out, modified hairs. Some of the species are monœcious, while others are diœcious. In the monœcious species the antheridia and oogonia occupy the same conceptacle (*B*, Fig. 181); the antheridia are produced as lateral branches of modified hairs

(*A*, Fig. 182); each antheridium is a thin-walled cell, whose protoplasm breaks up into a large number of bi-ciliate spermatozoids, which escape by the rupture of the surrounding wall (*B*, Fig. 182). Before rupturing, however, the antheridia detach themselves and float in the water with their contained spermatozoids.

354.—The oogonia are globular or ovoid short-stalked bodies, which develop from papillæ on the wall of the conceptacle. As each papilla elongates, it becomes divided into

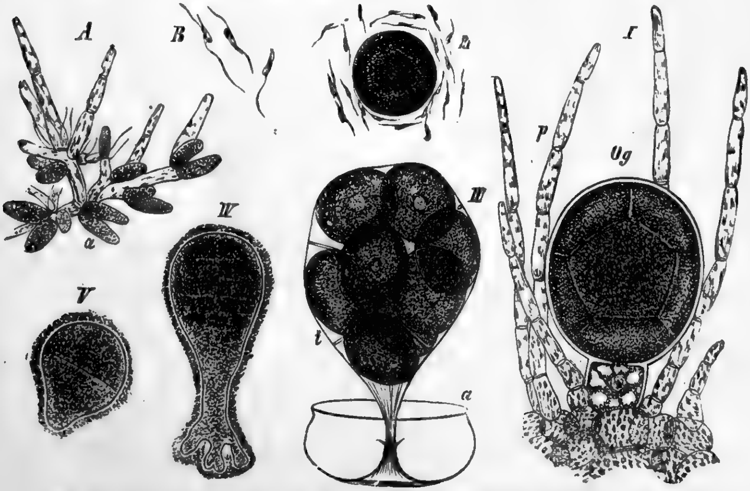


Fig. 182.—*Fucus vesiculosus.* *A*, branched hair bearing antheridia, *a*. *B*, spermatozoids. *I.*, *og*, oogonium, with contents divided into eight parts; *p*, paraphyses, or surrounding hairs. *II.*, commencement of the escape of the oospheres—the outer wall, *a*, of the oogonium has burst, the inner, *t*, is ready to open. *III.*, oosphere escaped, and surrounded by spermatozoids; *IV.*, *V.*, germination of the oospore. *B* × 330, all the rest 160.—After Thuret.

a basal and an apical portion by a transverse partition; the apical part enlarges, and (in the genus under consideration), its protoplasm divides into eight portions (*I*, Fig. 182), which eventually become spherical; it is thus an oogonium containing eight oospheres. The oospheres escape from the oogonium surrounded by an investing membrane, which floats out through the opening of the conceptacle, where it finally ruptures and sets the oospheres free (*II*, Fig. 182). The spermatozoids and oospheres are liberated at about the same

time, and the former gather around the inactive oospheres in great numbers, and by the vigor of their movements sometimes actually give them a rotatory motion (*III*, Fig. 182). The result of the coming together of the spermatozoids and the oospheres is the fertilization of the latter, and their transformation into oospores by the secretion of a wall of cellulose on each one. There is thus seen to be a close similarity between the fertilization of *Fucus* and of other Oosporeæ; particularly does it call to mind the sexual process in *Volvox* and its allies. When, however, the sexual organs proper, and their accessory organs, the conceptacles, are taken into the account, the relationship of *Fucus* to *Volvox* is seen to be much less than it appears to be at first sight.

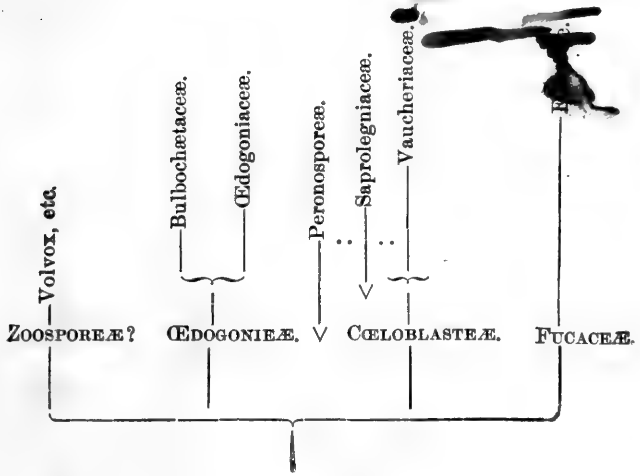
355.—The development of the oospore takes place at once; it lengthens and undergoes division into numerous cells, and at the same time it elongates below into root-like processes, which serve to hold fast the new plant (*V*, *IV*, Fig. 182). There is a gap in our knowledge of the life-history of these plants, extending from the young thallus to the fertile plant; probably when that is filled some plants now supposed to be distinct will be found to be forms or stages of these.

(*a*) The principal genera of *Fucaceæ* are *Fucus* and *Sargassum*. Of the first, *F. nodosus*, *F. furcatus*, and *F. vesiculosus* are the most common species on our Eastern coast; the latter also occurs on the Pacific coast; both are known as Rock-weeds. *Sargassum vulgare* is common on the Atlantic coast; *S. bacciferum*, the Gulf-weed, is found in the warmer parts of the several oceans, and in mid-Atlantic covers an immense tract known as the Sargasso Sea.

(*b*) The species of *Fucus* and *Sargassum* are washed ashore in great quantities during violent storms, constituting the bulk of the "wrack" of the coasts. They furnish valuable manure for enriching the soil, and are largely used for this purpose. From their ashes alkalies and iodine are obtained.

(*c*) In the Silurian period *Fucoides antiquus* represented the order Fucaceæ. In the Devonian period the order was abundantly represented. *Fucus*, *Sargassum*, and other genera were already in existence during Tertiary times.

ARRANGEMENT OF THE CLASSES AND ORDERS OF THE OOPHYTA.



CHAPTER XVII.

CARPOPHYTA.

356.—The distinguishing characteristic of the plants which constitute this vast division is the formation of a sporocarp, as a result of the fertilization of the female organ. The sporocarp consists, except in the simplest cases, of two parts essentially different from each other, viz., (1) a fertile part, which either directly or indirectly produces spores, sometimes a few, or even one, or, on the other hand, a very great number; (2) a sterile part, consisting of cells or tissues developed from the cells adjacent to the fertile part, and so formed as to envelop it. This group includes plants with chlorophyll, and a large number of species which are parasitic or saprophytic, and which, as a consequence, are destitute of chlorophyll. In the former, the sporocarp is small in proportion to the size of the vegetative parts of the plant; but in the latter, where the vegetative parts are greatly reduced, the sporocarp is proportionately large. In this the parasites and saprophytes of the Carpophyta are like those of the Phanerogams, in which the vegetative or assimilative organs are smaller than in those which contain chlorophyll; thus the very large sporocarp of many of the Ascomycetes and the Basidiomycetes, and their relatively small mycelium, may be compared to the large reproductive organs and the reduced stems and leaves of the *Rafflesiaceæ*.*

* This comparison must not be misunderstood. It does not imply homology of the parts compared, but it is intended to compare the vegetative and reproductive organs of the one group of plants, functionally considered, with those of the other. There can be no doubt that functionally the giant flower of *Rafflesia* is the equivalent of the sporocarp of a *Peziza*, while structurally they are not equivalent; in other words, they are analogues, but not homologues.

357.—The female organ is in this division called a *carpogonium*, which consists of a single cell (*e.g., Coleochæte*, some *Ascomycetes*, and the *Characeæ*), or of several cells (*e.g., Florideæ* and most *Ascomycetes*). In some cases a projection, called the *trichogyne*, is attached to the carpogonium; its function appears to be the conveyance to the carpogonium of the fertilizing influence received from the antheridium.

358.—The antheridium is here, as elsewhere throughout the Cryptogams, much more variable in structure than the female organ. In some cases it is applied to the carpogonium in fertilization, while in others it produces spermatozoids; in either case contact with the carpogonium is either direct (*Podosphæra, Characeæ*), or indirect, through a trichogyne (*e.g., Coleochæte, Florideæ, Peziza*).

359.—The plant-body shows in general a more perfect development in the Carpophyta than in the preceding divisions. While it is but little developed in the parasitic and saprophytic species, it is well developed in many of the *Florideæ* and the *Characeæ*. In these classes there is often a considerable amount of differentiation of the plant-body into caulome and phyllome.

§ I. Coleochæte.

360.—The genus *Coleochæte* may be taken to represent the simplest form of sexual reproduction in this division. The species are all small green fresh-water plants, composed of dichotomously branching filaments, which are arranged radially upon a central disc (or sometimes arranged upon irregularly branched threads); the diameter of each cushion-like mass is from 1 to 2 mm. (.04 to .08 in.).

361.—Reproduction takes place both sexually and asexually. The latter is by means of zoospores which arise in the vegetative cells, by the protoplasmic contents becoming, in each case, converted into a single spherical bi-ciliated zoospore, which escapes through a round hole in the cell-wall (*D*, Fig. 183).

362.—The sexual organs and process bear some resemblance to those of Œdogoniaceæ. The female organ, the

carpogonium, is a single cell, wide below, and tapering above into a long slender canal, the trichogyne, which is open at its apex (*A*, *og*, Fig. 183). The carpogonium is the terminal cell of a branch, which in its development swells up, while at the same time elongating into a tube. In the swollen basal portion there is a considerable mass of protoplasm, which is the essential part to be fertilized.

The male organs, the antheridia, are formed as flask-shaped protuberances which grow out of adjoining cells; they be-

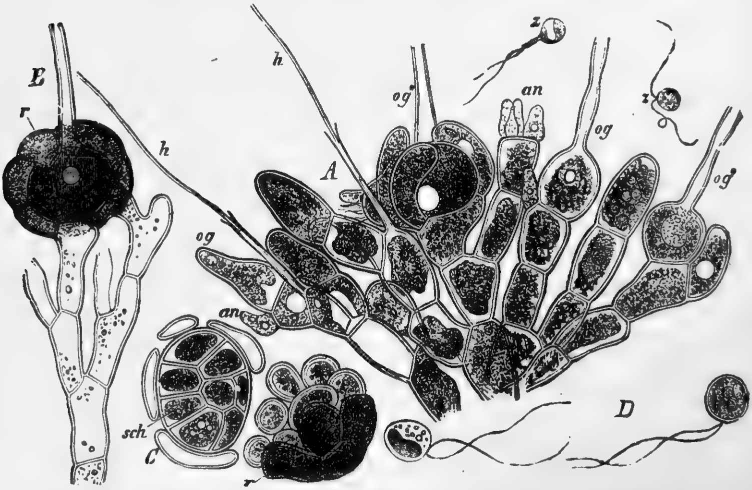


Fig. 183.—*Coleochæte pulvinata.* *A*, portion of fertile plant; *an*, antheridia; *og*, carpogonia—each with a trichogyne; *z*, *z*, spermatozoids; *h*, hairs, with sheathing bases. *B*, fertilized carpogonium surrounded by covering, *r* ("pericarp"), the whole constituting the sporocarp. *C*, sporocarps burst open, showing the interior tissue, *sch*; *r*, cortical cover ("pericarp"). *D*, zoospores (swarm-spores) from *C*. × 350.—After Pringsheim.

come cut off from the cells from which they grow, by transverse partitions. In each antheridium a single oval biciliate spermatozoid is formed (*A*, *z*, *z*, Fig. 183).

363.—Fertilization is doubtless effected by these spermatozoids coming in contact with the protoplasm of the carpogonium, but the actual entrance of the former has not yet been seen. After fertilization the protoplasmic mass in the carpogonium increases considerably in size, and becomes surrounded by a cellulose coat of its own. The cells which

support the carpogonium send out lateral branches, which grow up and closely invest it, and by their growth finally cover it entirely (excepting the trichogyne) with a cellular "pericarp" (*B*, *r*, Fig. 183). The whole mass, including the fertilized carpogonium and its investing "pericarp," constitutes the simplest form of *sporocarp.*

364.—The germination of the sporocarp takes place (the next spring) by the swelling of the protoplasmic contents, and the consequent rupture of the "pericarp;" the inner portion becomes changed into a many-celled mass (*C*, Fig. 183), which gives rise to bi-ciliate zoospores closely resembling those developed from the vegetative cells. From each zoospore a new plant eventually arises.

(*a*) These little plants occur in fresh-water pools as little green masses adhering to leaves, sticks, etc. According to Wolle, we have five species.

(*b*) The sexual process and the development of the sexual organs occur in May, June, and July.

(*c*) Nothing can be attempted in this place to determine the grouping of *Coleochæte* with other Carpophyta. Its evident relationship to the Perisporiaceæ in the Ascomycetes suggests that possibly the latter class may have to be broken up, and the first two orders united with *Coleochæte* to form a new class. Certainly the relationship between *Coleochæte*, Perisporiaceæ, and Tuberaceæ is much closer than between the two last named and the other orders of Ascomycetes. There can be but little doubt that the Ascomycetes are held together by characters which are now of but secondary value, drawn as they are from the asexual fruiting, while characters which are of far greater value, derived from the sexual organs, are disregarded.

§ II. Class Florideæ.

365.—In the Florideæ the reproduction is generally asexual as well as sexual. The former is by means of cells which originate from a division of a mother-cell into four parts; on account of their number they have received the name of *tetraspores* (*A*, *B*, *t*, *t*, Fig. 184). These appear to replace the swarm-spores of other algæ, and may also be compared to the conidia of certain fungi; they are destitute of cilia, and are, as a consequence, not locomotive. They develop from the terminal cells of lateral branches, or from the cells of ordinary thick tissues, sometimes deeply imbedded.

366.—The sexual organs consist, as in *Coleochæte*, of carpogonia and antheridia. The latter are composed of one or more mother-cells, situated singly or in groups on the ends of branches (*A* and *B*, *a*, *a*, Fig. 185). The spermatozoids are small, round bodies, which are destitute of cilia, and, as a consequence, incapable of independent movement (*A*, *x*, Fig. 185); they are carried about by currents of water, and in this way brought to the carpogonia.

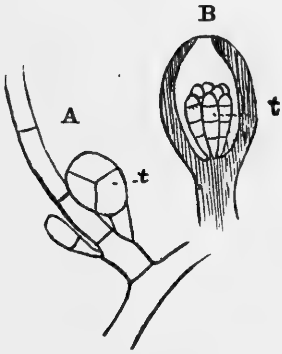


Fig. 184.—Tetraspores of Florideæ. *A*, of *Lejolisia mediterranea*; *t*, tetraspores.—After Sachs *B*, of *Corallina officinalis*; *t*, tetraspores in a cup-shaped extremity of a branch.—After Berkeley.

367.—The carpogonia are somewhat variable as to their complexity, being much more simple in the lower orders than in the higher. In the genus *Nemalion* the carpogonium consists of a single cell (*B*, *b*, Fig. 185), resembling *Coleochæte* closely in this respect. It is thickened below, and elongated above into the trichogyne, which differs from that in *Coleochæte* in not being open at the top. When the spermatozoids are set free from the antheridia they attach themselves to the trichogyne, as shown in Fig. 185; the result of this contact of the spermatozoids with the trichogyne is the fertilization of the carpogonium, which immediately enlarges, and at the same time undergoes division into many cells, which grow into short, crowded branches, bearing a spore at the end of each (*D* and *E*, Fig. 185). To this growth, which includes the spores and the short branches which bear them, and which resulted from the fertilization of the carpogonium, the name of *sporocarp* is applied. In the genus under consideration the sporocarp is a comparatively simple growth, as compared with the degree of complexity it reaches in some other orders of this class.

368.—In the genus *Lejolisia*, the carpogonium, before fertilization, consists of several cells (*A*, *b*, Fig. 185); the trichogyne is in connection with certain of the exterior cells of the carpogonium, but not directly with its central cell.

Upon fertilization taking place, which is as in *Nemalion*, the peripheral cells of the carpogonium (excepting those constituting the *trichophore—i.e.*, the trichogyne-bearer) undergo division, and become developed into articulated branches, which lie side by side, and form a more or less spherical

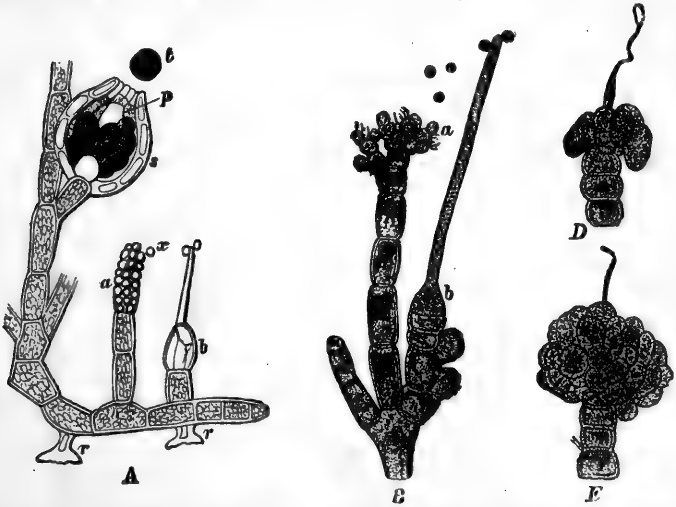


Fig. 185.—*A, Lejolisia mediterranea.* *r*, root-like processes (rhizoids); *a*, antheridium; *x*, spermatozoids; *b*, carpogonium, with trichogyne, to the apex of which two spermatozoids are attached; *s*, section of ripe sporocarp; *t*, ripe spore escaping. *B*, *Nemalion multifidum.* *a*, branch with antheridia and spermatozoids; *b*, carpogonium, with trichogyne, the latter with spermatozoids attached to its apex. *D* and *E*, development of the sporocarp of *Nemalion.* × 150.—After Bornet.

organ, the so-called "pericarp." In the meantime the central cell of the carpogonium develops processes or outgrowths which eventually become spores, occupying the cavity of the "pericarp" (*A, s*, Fig. 185). An interesting fact in this connection is that neither the trichogyne nor trichophore take part in the development subsequent to fertilization; in other words, the cells which directly receive the influence of the spermatozoids do not themselves undergo a subsequent development, but adjoining ones do develop, on the one hand, into the spores, and on the other into the filaments of the pericarp. The sporocarp in this genus is thus seen to be somewhat more complex than in *Nemalion*, including

the pericarp, in addition to the parts found in the latter genus.

369.—In the genus *Dudresnaya* there is a curious and complicated sexual process. After the fertilization of the trichogyne, a long "connecting tube" (*ct*, Fig. 186) grows out from beneath the trichophore, and comes in contact with the fertile branches (*f, f*, Fig. 186), to the terminal cells of which it becomes closely applied. These fertile branches, which grow as lateral branches on the same plant as the trichogyne, are the true female organs, and fertilization is consummated only when the connecting tube comes in contact and coalesces with them. The result of this curious process is the production of a sporocarp on each fertile filament.

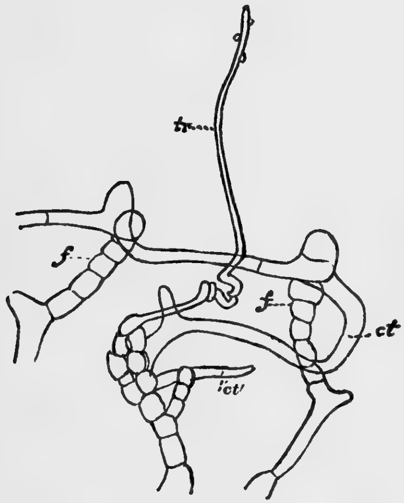


Fig. 186.—*Dudresnaya purpurifera. tr*, trichogyne, with spermatozoids attached; *ct*, connecting-tube which grows out from below the base of the trichogyne, and comes in contact with the fertile branches, *f, f*; *ct'*, young connecting-tube.—After Thuret and Bornet.

(*a*) This class is a large and interesting one, but unfortunately it cannot be studied readily except near the seaside, and even then, from the fact that the species mostly inhabit the deeper waters, it presents many difficulties. The plants are mostly red or violet in color, although this is not due to the absence of chlorophyll. The red color is due to the presence of a pigment (*phycoërythrine*), which is soluble in cold fresh water; its solution is carmine-red in transmitted light and reddish yellow in reflected light. Upon extraction of the phycoërythrine the plants are found to be green from the presence of the chlorophyll which had been masked by the brighter pigment.

(*b*) There are many orders in this class, the following of which are represented in the United States.*

* The sequence of the orders is that given by Dr. Farlow in his "List of the Marine Algæ of the United States," 1876, published in the

Order *Rhodomeleæ*, of which *Dasya* and *Polysiphonia* are common genera.

Order *Chylocladieæ*, represented by only two Californian species.

Order *Sphærococcoideæ*, represented abundantly by species *Delesseria*.

Order *Corallineæ*, containing plants which are remarkable for the large amount of calcium carbonate they contain. *Corallina* is abundant.

Order *Gelidieæ*, represented by *Gelidium*.

Order *Hypneæ*, including only a few species of one genus *Hypnea*.

Order *Rhodymenieæ*, of which *Rhodymenia* and *Lomentaria* are common genera. *Rhodymenia palmata*, the "Dulse" of our coasts, is used as human food.

Order *Spongiocarpeæ*, with one species of *Polyides*.

Order *Squamarieæ*, with one species of *Peyssonnelia*.

Order *Batrachospermeæ*, to which *Nemalion* (Fig. 185, *B*) belongs.

Order *Wrangelieæ*, with two species of *Wrangelia*.

Order *Gigartineæ*, of which *Chondrus crispus*, the Irish moss so largely used for food, for making blanc mange, etc., is the best-known of the many species on our coasts.

Order *Cryptonemieæ*, represented mainly on our Southern and Pacific coasts. *Schizynemia edulis*, of Europe and our Western coasts, is used as human food.

Order *Dumontieæ*, to which *Halosaccion* of our Eastern coast belongs.

Order *Spyridieæ*, represented by *Spyridia* of our Eastern coast.

Order *Ceramieæ*. This order contains algæ "which are either strictly monosiphonous (*i.e.*, composed of a single tube) and filiform, or which are more simple in their structure than others, approaching in this respect the Confervaceæ. It abounds in species which display the most exquisite combination of ramification and coloring." A large portion of our marine flora is composed of individuals of this order, as "they abound on our coasts in every little rocky pool, on every piece of woodwork exposed to the waves, on rocks and stones, and, above all, on the stems of the larger or firmer algæ, or even on marine Phanerogams, which they fringe in the most exquisite way with every shade of red, from a bright rose to purple."†

Lejolisia (*A*, Fig. 185) and *Dudresnaya* (Fig. 186) are genera of this order. *Callithamnion* is represented by many species on both our At-

---

Report of the U. S. Fish Commissioner for 1875. It is modified from Thuret's arrangement. The arrangement of the orders and the grouping of genera into orders are not based upon sexual characters, and consequently must be regarded as to a considerable extent artificial. The first-named orders in the list are higher than those that follow.

† "Introduction to Cryptogamic Botany," by M. J. Berkeley, 1857, p. 178. The student is also referred to Harvey's "Nereis Boreali-Americana," a "Contribution to a History of the Marine Algæ of North America," published by the Smithsonian Institution, 1852 to 1858.

lantic and Pacific coasts. *Ceramium rubrum* is a very common species.

(*c*) The order Corallineæ was represented in the Silurian by a species of *Corallina*. Others occur in the Secondary (Jurassic) and Tertiary. *Chondrites* represented the order Gigartineæ from the Permian to the Tertiary (Miocene). The order Sphærococcoideæ was represented in the Secondary by Jurassic species of *Sphærococcites*, and in the Tertiary by *Delesseria*. In the order Rhodomeleæ a species of *Polysiphonides* occurs as a fossil in the Tertiary.

§ III. Class Ascomycetes.

370.—This large class includes chlorophyll-less plants which differ much in size and appearance, but which agree with one another, and differ from all other Carposporeæ in producing their spores (*ascospores*) in sacs (*asci*). The sexual reproductive organs, consisting of carpogonia and antheridia, are produced upon the mycelium, and, after fertilization, a sporocarp, which includes the asci and ascospores, is developed. The asci are, at first, single cells at the ends of branches which result from fertilization of the carpogonium; in these, ascospores arise by internal cell-formation. The most common number of ascospores is eight in each ascus, but it sometimes exceeds, and frequently falls short, of this number, there being often no more than one or two. The asci are in many cases arranged side by side in a compact mass, forming a spore-bearing surface, the *hymenium*. In addition to the ascospores there are generally one or several other kinds of spores, which are developed on the same mycelium as the sexual organs, or on another, the latter case being one of an alternation of generations.

371.—The Ascomycetes are readily separated into a number of well-marked groups, which may not all turn out to be coördinates. For the present they may be treated as orders.

372.—Order Perisporiaceæ (or Erysiphaceæ). In this order the plants, which are mainly parasitic, are composed of branching articulated filaments, which form a white web-like film upon the surface of the leaves and stems of their hosts. There are both sexual and asexual spores, and of the latter there are in most cases two or three different kinds, which are produced earlier than those that result from a fer-

tilization. The sexual organs and the sporocarp resulting from the act of fertilization bear a striking resemblance to those of *Coleochæte*, the difference being such as may be accounted for by considering the aquatic habits of the one, and the aerial and parasitic or saprophytic habits of the other.

373.—In the parasitic *Perisporiaceæ* the jointed filaments of the mycelium closely invest and cover the leaves and other tender parts of their hosts, and draw nourishment from them by means of haustoria, which project as irregular pullulations from the side of the hyphæ next to the epidermis (Fig. 187); these haustoria apply themselves closely to the epidermis cells, and, in some cases at least, appear to penetrate them.* The crossing and ramifying hyphæ soon send up many vertical branches, in which partitions form at regular intervals; the cells thus formed are at first oblong and cylindrical, with flattened ends; but the topmost one soon becomes rounded at its extremities, and the others follow in quick succession, thus giving rise to a moniliform row of loosely attached elliptical or rounded cells, the *conidia* (*I*, Fig. 188). These fall off and germinate at once by pushing out a germinating tube, which gives rise to a new mycelium.

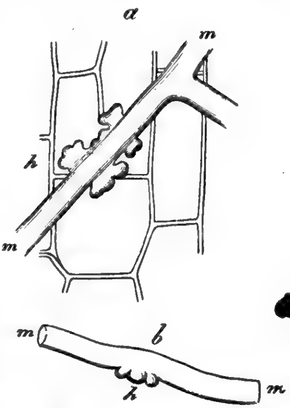


Fig. 187. — *Erysiphe (Oidium) Tuckeri.* *a*, a piece of a vegetative hypha, *m*, *m*, upon a fragment of the epidermis of the leaf of the vine, and to which it is fastened by the haustoria. *h*; *b*, an isolated piece of a vegetative hypha, with the haustorium. *h*, seen in side view. × 370.—After Von Mohl.

374.—The sexual process, which in most species takes

* De Bary ("Morphologie und Physiologie der Pilze," etc., 1865, p. 19) says that the haustoria of the investigated species do not penetrate into the epidermis cells; while Sachs ("Lehrbuch, 4te Auflage," 1874, p. 312) says that haustoria are sent into the epidermis cells. A mycelium on *Poa pratensis* (probably of *Erysiphe communis*) examined in 1877 appeared to have sent its haustoria through the outer walls of the epidermis cells.

place late in the season, is as follows: where two filaments cross each other or come into close contact they swell slightly and send out from each a short branch; one of these thickens and assumes an oval form, becoming at the same time separated from the filament by a partition; this is the carpogonium (*III*, *c*, Fig. 188, and *c*, Fig. 189). From the swollen part of the other filament a corresponding branch is given off, which grows up in contact with the carpogonium; near its extremity it forms a partition, which thus cuts

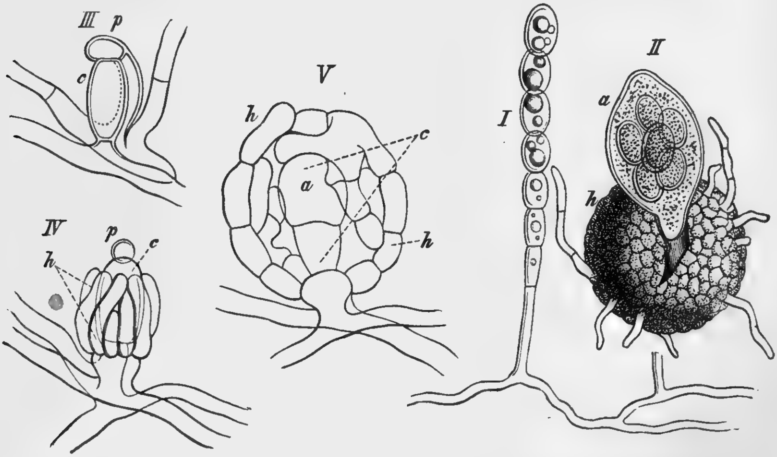


Fig. 188.—*I.*, conidia-bearing hypha of *Sphærotheca pannosa*. *II.*, the ripe sporocarp of the same; *a*, the single ascus escaping from the perithecium, *h*; only a few of the hypha-like appendages of the perithecium are shown. *III.*, sexual organs of the same; *c*, carpogonium; *p*, antheridium. *IV.*, the formation of the perithecium by the growth of the enveloping cells, *h*; *c*, carpogonium; *p*, antheridium. *V.*, section of the young sporocarp of *Sphærotheca Castagnei*; *c*, carpogonium; *a*, the young ascus; *h*, *h*, cells of the perithecium. *I.* and *II.* after Tulasne; *III.*-*V.* after De Bary.

off a small rounded terminal cell, the antheridium (*III.*, *p*, Fig. 188, and *b*, Fig. 189). Immediately after the formation of the antheridium the effect of fertilization shows itself in the growth from below the base of the carpogonium of eight or ten branches, which join themselves to its sides and to one another, finally completely investing it (*IV.*, Fig. 188, and *d*, Fig. 189). Each of these joined enveloping branches becomes transversely divided several times, thus giving to the covering layer a distinctly cellular structure. The enclosed

carpogonium becomes divided in such a way that from one portion of it an inner layer of cells is formed in contact with the outer envelope described above. From the remaining central part of the carpogonium one ascus (in *Sphærotheca* and *Podosphæra*), and in the other genera two or more, are developed. In each ascus from two to eight ascospores arise by internal cell-formation (*II, a*, Fig. 188). The sporocarp (technically called the *perithecium*) becomes dark and hard, and from its outer cells there grow out long filaments (technically known as *appendages*), which are usually septate, and of a particular shape in each genus; thus in *Podosphæra* and *Microsphæra* they are dichotomously branched; in *Phyllactinia* they are straight and needle-shaped; in *Uncinula* they are curved regularly at their tips (Fig. 190), while in the other genera they are tortuous, and simple or irregularly branched. The perithecia remain during the winter upon the fallen and decaying leaves, and finally, by rupturing, permit their asci, with their contained ascospores, to escape.

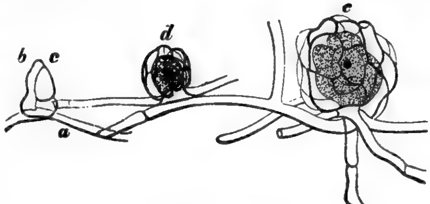


Fig. 189.--The sexual process in *Erysiphe Cichoriacearum*. *a*, threads of mycelium; *b*, antheridium; *c*, carpogonium; *d*, young sporocarp; *e*, older sporocarp. Highly magnified.—After Œrsted.

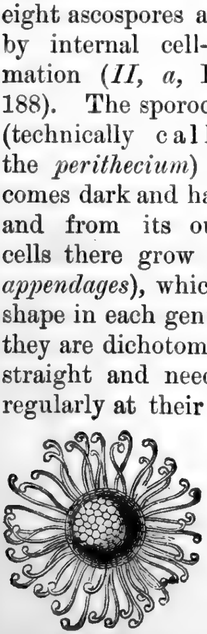


Fig. 190.—Ripe sporocarp of *Uncinula adunca*; the appendages of the perithecium are curved in a circinate manner at their free extremities.—After Cooke.

375.—There are usually present some other organs, which bear small spore-like bodies, but whose function is not certainly known. These organs, which are known as *pycnidia*, are clavate, ovate, or nearly spherical in shape; the bodies they contain (the so-called pycnidio-spores) in their cavities are usually oblong or elliptical.

376.—In the genus *Eurotium* (composed of saprophytes) the conidia are produced in a slightly different way. The mycelium, which is common on articles of food, as bread, pastry, preserved fruit, etc., and on poorly dried specimens in

the herbarium, sends up vertical hyphæ, which swell up at the top, and bear a large number of small protuberances or branches, the *sterigmata* (*A*, *c*, *st*, Fig. 191). Each sterigma produces gradually a long chain of conidia, so that each

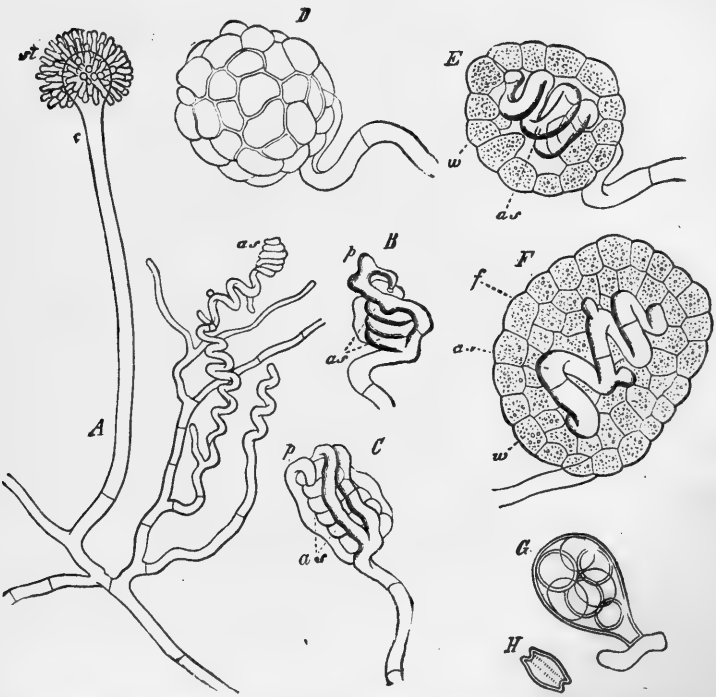


Fig. 191.—*Eurotium repens.* *A*, a portion of the mycelium, with erect hypha, *c*, bearing at its top a radiating cluster of sterigmata, *st*, from which the conidia have fallen; *as*, young carpogonium—below it a younger branch is beginning to coil spirally to form another carpogonium. *B*, the carpogonium, *as*, and the antheridium, *p*. *C*, the same beginning to be surrounded by the enveloping branches which grow out from its base. *D*, sporocarp. *E*, *F*, sections of unripe sporocarps; *w*, outer wall; *f*, inner cells of sterile tissue; *as*, developing carpogonium, giving rise to branches from which asci are produced. *G*, an ascus containing eight ascospores. *H*, ripe ascospore. Highly magnified.—After De Bary.

vertical hypha is terminated by a round mass, made up of these radiating strings of conidia. The sexual organs appear a little later than the conidia. The end of a branch of the mycelium becomes coiled into a hollow spiral (*A*, *as*, Fig.

191), which constitutes the carpogonium, and which is soon divided by cross-partitions into several cells. From below the spiral there pushes out a branch (the antheridium), which grows upward, and brings its apex in contact with the upper cells of the carpogonium (*B*, Fig. 191). After this process, which constitutes fertilization, other branches grow up around the carpogonium, and finally completely enclose it, as in the parasitic genera described above (*C*, *D*, *E*, and *F*, Fig. 191). By the subsequent growth and division of the enveloping branches, the carpogonium becomes imbedded in a thick parenchymatous mass. In the meantime, from the cells of the carpogonium branches bud out and penetrate the surrounding parenchyma (*F*, Fig. 191), and finally produce eight-spored asci on their extremities (*G*, Fig. 191); after a time the asci are dissolved, and the sporocarp, now of a sulphur-yellow color, contains only loose ascospores, intermingled with the *débris* of the broken-up asci and parenchyma.*

The plants of this order are abundant and easily studied. The following partial list will enable the student to intelligently begin his investigations:

PARASITIC PLANTS.

A. Perithecium containing a single ascus.

Appendages floccose..................	Genus,	*Sphærotheca.*
Appendages dichotomous...............	"	*Podosphæra.*

B. Perithecium containing many asci.

Appendages needle-shaped, rigid.......	Genus,	*Phyllactinia.*
Appendages hooked....................	"	*Uncinula.*
Appendages dichotomous..............	"	*Microsphæra.*
Appendages floccose..................	"	*Erysiphe.*

Sphærotheca pannosa occurs on wild gooseberries, on whose stems, leaves, and fruits it forms brown felted masses. In its conidial stage it is frequently so abundant on the leaves of roses as to entirely destroy them.

S. Castagnei sometimes occurs upon the hop in such abundance as to destroy the crop.

---

* The student is referred to De Bary's "Morphologie und Physiologie der Pilze," etc., 1865, p. 162. A translation of the part relating to the *Erysiphei* appeared in "Grevillea," Vol. I., p. 152.

Podosphæra Kunzei may be found on the leaves of the cherry and apple, which it injures greatly in some cases; the conidia may be observed in midsummer, and the sexual process and formation of perithecia in autumn.

Phyllactinia guttata may be obtained in great abundance in autumn upon the leaves of the hazel and ironwood.

Uncinula adunca is frequently abundant on willow leaves in the autumn (Fig. 190).

U. spiralis is the species to whose conidial stage the name *Oidium Tuckeri* has hitherto been applied in this country. It occurs on the grape, and does great injury. According to Dr. Farlow, it is not certain that the so-called *Oidium Tuckeri* of this country is identical with what is so named in Europe, and which is even more injurious to grapes in that country than in this.

U. circinata occurs on the leaves of the red and silver maples in the autumn.

Microsphæra Friesii is one of the most common species. It may be found in the conidial stage at any time during the summer on the leaves of the lilac, and late in summer or in autumn the perithecia are usually abundant.

M. extensa is a nearly related species, often very common on oak leaves.

Erysiphe lamprocarpa, which may be found on Compositæ (especially on *Helianthus*), and also on wild verbenas, is readily distinguished by its two-spored asci. The commonness of this species makes it a valuable one for study.

E. tortilis may be frequently obtained on the leaves of the Virgin's Bower.

E. Martii occurs in great abundance upon cultivated peas, greatly to their injury. In summer it covers the leaves and fruits with a white mould-like growth, which is the conidial stage of the parasite; as autumn approaches the mycelium becomes darker, and finally large numbers of perithecia may be found.

E. communis appears in early summer on grass leaves, where the vegetation is rank. In autumn the perithecia may be found in abundance on Ranunculaceæ (especially on *Anemone*) growing in grass.

Saprophytic Plants.

Eurotium herbariorum may be readily obtained for study by placing a few green specimens of Phanerogams in an ordinary plant-press and permitting them to remain until they become mouldy. The conidial stage, which first appears, is what has long been described as a distinct fungus under the name of *Aspergillus glaucus;* somewhat later the bright yellow perithecia will be found in abundance.

377.—Order Tuberaceæ. In this order the sporocarp is a rounded underground mass, composed of pseudo-parenchyma and the asci with their contained ascospores. In the Truffle (*Tuber*) the sporocarp is large, and dark colored and warty on the exterior. Internally it contains narrow tortuous chambers, on whose walls are the asci, containing two to eight usually areolate or echinulate ascospores (Fig. 192, *A* and *B*). The sexual organs, as well as the early stages of the Truffles, are unknown.

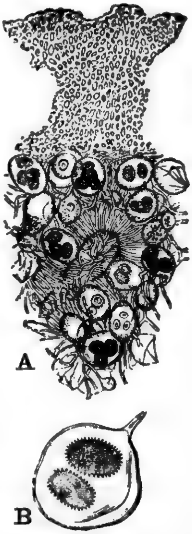


Fig. 192.—*Tuber melanosporum.* *A*, a portion of a transverse section, showing the asci, with contained ascospores; *B*, an ascus with ripe ascospores. Both much magnified.—After Tulasne.

378.—The common blue mould, found on all sorts of decaying bodies, and known as *Penicillium glaucum* (or *P. crustaceum*), has recently been found by Brefeld to be a member of this order. Its life-history is now pretty well known, and it indicates what the early stage of the Truffle must in all probability turn out to be. In *Penicillium* the mycelium sends up a large number of vertical hyphæ, which branch at the top, and produce chains of conidia (Fig. 193). It appears, from Brefeld's researches, that this stage is the only one which the plant passes through under ordinary circumstances; by careful culture, however, he succeeded in making it pass into its sexual stage. He found the sexual organs to be in all essentials similar to those of *Eurotium* (Fig. 191); like it, the carpogonium is a spirally twisted end of a hypha, and the antheridium a branch growing out from below it. The subsequent development is also much as in *Eurotium;* a thick covering forms over the fertilized carp-

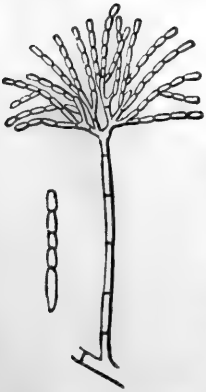


Fig. 193. — *Penicillium chartarum*, showing conidia-bearing hypha; at the side is shown an isolated chain of conidia. Magnified.—After Cooke.

ogonium by the growth of many basal enveloping branches, and inside of this the carpogonium increases in size, and sends out branches, which finally produce eight-spored asci. The little tuber-like mass thus formed is yellowish, and of the size and appearance of a coarse sand grain.

(*a*) Aside from *Penicillium*, we have in this country very few representatives of this order. Two or three species of *Tuber* have been recorded, and two of *Elaphomyces*.*

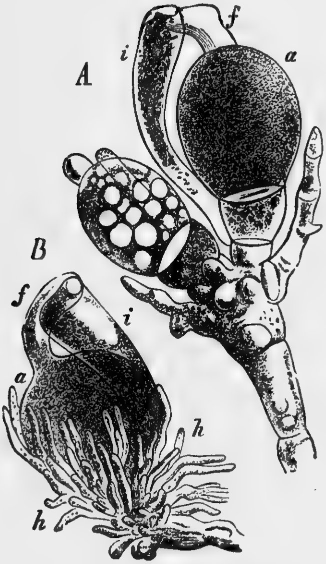


Fig. 194.—Sexual organs of *Peziza confluens*, highly magnified. *A*, at time of fertilization; *a*, carpogonium; *f*, trichogyne; *i*, antheridium. *B*, after fertilization; *h*, *h*, the hyphæ from which the receptacle is developed.—After Tulasne.

(*b*) In Europe, where they grow abundantly, *Tuber æstivum*, *T. melanosporum*, and *T. magnatum* are gathered for food. They are found by the aid of dogs and pigs, which are trained to search for them.

379.—Order Helvellaceæ (or Discomycetes). These are for the most part disc-like or cup-like saprophytes, which frequently attain large dimensions. The hymenium is spread over the upper and generally exposed surface of the full-grown plant, which is in reality the sporocarp.

In *Peziza*, one of the principal genera, the sexual organs occur on the mycelium on or in the ground; the ends of certain hyphæ swell up into ovoid vesicles, the carpogonia (Figs. 194 and 195), each of which is provided with a more or less bent and curved appendage, the *trichogyne* (Fig. 195, and *f*, *f*, Fig. 194). From below the carpogonium a branch grows out, and, curving around, becomes closely applied by its tip to the extremity of the trichogyne (Figs. 194 and 195). The

* See *Bulletin of the Torrey Botanical Club*, November, 1878, for the species of *Tuber* discovered in North America.

immediate result of this process of fertilization is the budding out and upward growth of a large number of hyphæ from beneath the carpogonium (*B*, Fig. 194); these form a dense felted mass, from which, eventually, there rise vertical, closely crowded hyphæ, which form the hymenium (*A*, *h*, Fig. 196). In the terminal portions of certain of the vertical hyphæ the protoplasm condenses around certain points, and thus gives rise to ascospores (*B*, *a* to *f*, Fig. 196). In this genus (*Peziza*), as well as most others of this order, the ascospores are always eight in each ascus. At matur-

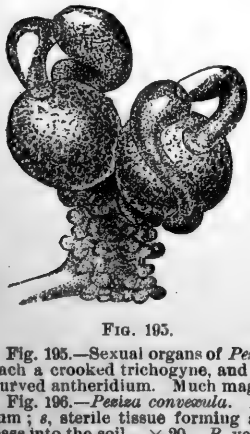


FIG. 195.

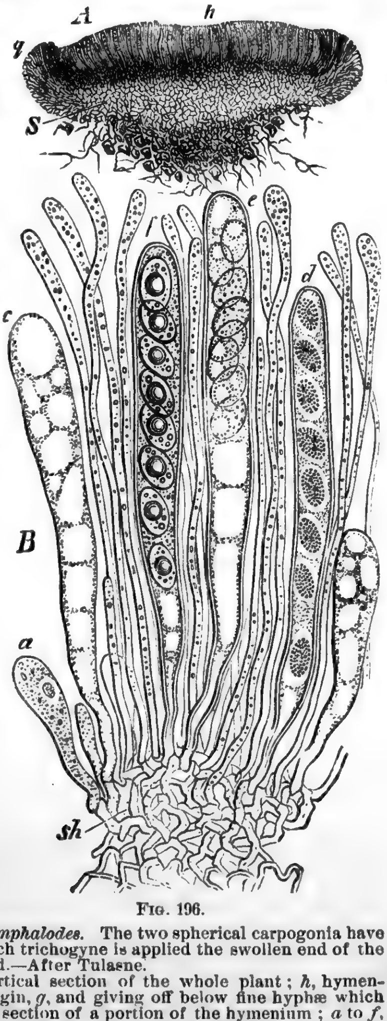


FIG. 196.

Fig. 195.—Sexual organs of *Peziza omphalodes*. The two spherical carpogonia have each a crooked trichogyne, and to each trichogyne is applied the swollen end of the curved antheridium. Much magnified.—After Tulasne.

Fig. 196.—*Peziza convexula*. *A*, vertical section of the whole plant; *h*, hymenium; *s*, sterile tissue forming a margin, *g*, and giving off below fine hyphæ which pass into the soil. × 20. *B*, vertical section of a portion of the hymenium; *a* to *f*, asci, with ascospores in various stages of development, intermixed with slender paraphyses; *sh*, sub-hymenial hyphæ. × 550.—After Sachs.

ity the ascospores escape by the rupture of the walls of the asci, this generally taking place at the upper or free end.

380.—In *Ascobolus* the carpogonium consists of a row of cells ; it develops from the end of a branch of the mycelium, which becomes curved and divided by several partitions (*c*, Fig. 197). On account of its peculiar shape it is frequently spoken of as the "vermiform body," or *scolecite*. From another portion of the mycelium an elongated and branched antheridium rises, and comes in contact with the free end of the carpogonium (*l*, Fig. 197); after this process numerous filaments branch from the middle cell of the carpogonium and pass upward, eventually producing asci (*s* and *a*, Fig. 197). At the same time an abundant growth of hyphæ takes place from the mycelium below the carpogonium, and from this the greater part of the mass of the fruiting plant is produced; it also invests the hymenium, forming the so-called pericarp which encloses it (*r*, Fig. 197). Vertical branches of the sterile tissue also pass into the hymenial layer and constitute the paraphyses.

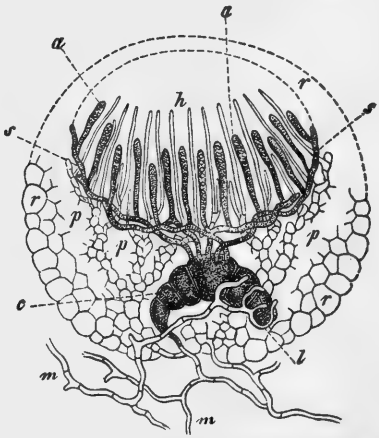


Fig. 197.—Diagrammatic vertical section of the sporocarp of *Ascobolus furfuraceus*. *m*, *m*, mycelium; *c*, carpogonium; *l*, antheridium; *s*, branches bearing the asci, *a*, *a*; *p*, *p*, pseudoparenchymatous sterile tissue; *r*, *r*, cortical portion of sterile tissue—above it forms the so-called pericarp, which surrounds and encloses the hymenium, *h*.—After Janczewsky.

381.—The asexual reproductive bodies are but little known, but enough is known to indicate that there is at least a conidia-bearing stage for these Ascomycetes, as for all others. De Bary has shown that the early stage of the little plant known as *Peziza Fuckeliana* is mould-like in appearance, in fact having been described as a mould under the name of *Polyactis cinerea*. In this stage it grows upon dead grape leaves, sending its mycelium through the dead tissues. Its vertical hyphæ produce clusters of oval conidia, which are much like those produced in the corresponding stage of

Eurotium and *Penicillium.* In another species, *Peziza fusarioides,* the conidial stage has been pretty certainly determined to be the growth which was formerly supposed to be a species of *Dacrymyces;* it consists of little tubercles which contain slender linear bodies on branched threads. *Bulgaria sarcoides* is known to bear conidia in an earlier stage, which was formerly referred to the genus *Tremella* (Hymenomycetes).*

(*a*) The principal genus of this order is *Peziza,* which contains many species; they are common on the ground in forests. *Ascobolus furfuraceus* is common on cow dung. *Morchella esculenta,* the Morel, grows on the ground in forests. It attains a height of from 10 to 15 centimetres (4 to 6 inches), and bears its hymenium in shallow depressions of its convex surface.

(*b*) The Morel is edible, and is much used for food in some places. According to Dr. M. A. Curtis, some species of *Helvella,* also, are edible.

(*c*) *Peziza sylvatica, P. candida,* and *Cenangium Piri* occur as fossils in the Tertiary.

382.—Order Pyrenomycetes. The plants of this order are parasitic or saprophytic in habit; their tissues are usually hard and somewhat coriaceous, differing in this respect from the *Helvellaceæ,* which are generally fleshy; they differ also from the plants of the last-named order in having the hymenium imbedded in deep cavities (*perithecia*) with narrow openings. In other respects the *Pyrenomycetes* present a close similarity to the *Helvellaceæ,* to which they are doubtless closely related.

383.—Their general structure may be illustrated by a couple of examples. In *Claviceps purpurea,* the fungus which produces ergot on rye and other grasses, the first stage consists of a profuse growth of the mycelium in the tissues and upon the surface of the young ovary (*s*, *A*, and *B*, Fig. 198). In this stage, which is called the Sphacelia stage, it produces a multitude of conidia on the ends of hyphæ which grow out at right angles to the surface of the mycelial mass (*C*, Fig. 198, *b* and *p*); these conidia fall off very easily, and quickly germinate (*D*, Fig. 198), giving rise under favorable circumstances to new sphacelia, which in turn may produce conidia, and these, new sphacelia, and

* See further, De Bary, op. cit., p. 200.

so on. The contact of an infected head of rye with an uninfected one is sufficient to communicate the fungus to the latter, and doubtless the conidia are also freely carried by the winds, and, to a certain extent, by insects. It appears that, in some cases at least, the germinating conidia produce, first, short hyphæ, which bear a few small spores (*sporidia, D*, Fig. 198, *x*), which themselves germinate, and then produce the sphacelia; it is doubtful, however, whether this always takes place.

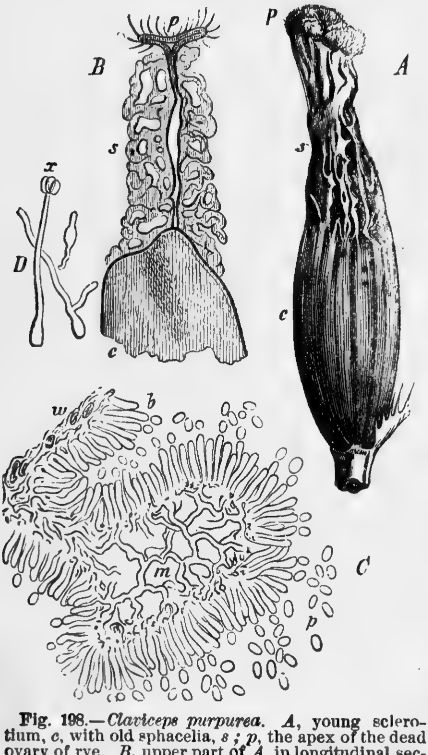


Fig. 198.—*Claviceps purpurea.* *A*, young sclerotium, *c*, with old sphacelia, *s*; *p*, the apex of the dead ovary of rye. *B*, upper part of *A*, in longitudinal section, showing sphacelia, *s*. *C*, transverse section through the sphacelia more highly magnified; *m*, the mycelium, surrounded with the hyphæ *b*, bearing conidia; *p*, conidia fallen off; *w*, the wall of the ovary. *D*, germinating conidia, forming sporidia, *x*. *A* and *B* moderately, *C* and *D* highly magnified.—After Sachs.

384. — After the conidial stage, the mycelium at the base of the ovary becomes greatly increased, and assumes a hard and compact form; it grows with a considerable rapidity, and carries up on its summit the old sphacelia and the remains of the now-destroyed ovary (*A* and *B*, Fig. 198). The compact, horn-shaped, and dark-colored body which results is called the *sclerotium;* that which is produced upon rye is from one to three centimetres long (.4 to 1.2 in.) and from two to six millimetres in diameter (.08 to .25 in.); on other grasses it is usually of less size. The sclerotium occupies the position of the displaced ovary, and in the autumn

falls to the ground, where it usually remains till the following spring, when its hyphæ begin a new growth. As a result of this new growth several little branches shoot up, and each forms a globular head (the receptacle) at its summit (*A*, Fig. 199). Large numbers of flask-shaped perithecia form in the cortical region of the receptacles (*B*, Fig. 199, *cp*); each contains many elongated asci, which rise from the bot-

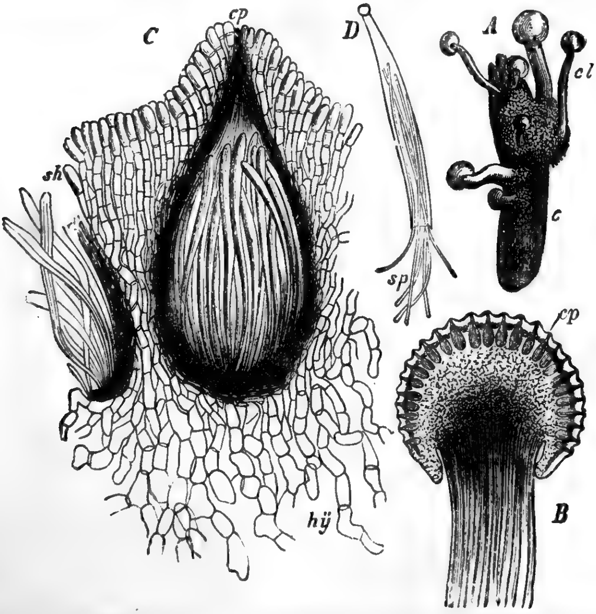


Fig. 199.—*Claviceps purpurea.* *A*, a sclerotium (ergot), *c*, forming the receptacles (sporocarps ?), *cl*. *B*, longitudinal section of a receptacle, showing the perithecia, *cp*. *C*, a perithecium, with the surrounding tissue; *cp*, its orifice; *hy*, hyphæ of the receptacle; *sh*, outer layer of the receptacle. *D*, a single ascus, ruptured, permitting the elongated narrow ascospores, *sp*, to escape. *A* and *B* moderately, *C* and *D* highly magnified.—After Tulasne.

tom of the cavity (*C*, Fig. 199), and themselves contain several greatly attenuated ascospores (*D*, Fig. 199, *sp*). The ascospores germinate under proper conditions, and produce sphacelia, thus completing the round of life.

385.—Thus far no sexual organs have been found, but from the general similarity of these fungi to the *Pezizæ* and other Helvellaceæ, it may be surmised that sexual organs and

a sexual process precede the formation of each receptacle which springs from the sclerotium. It may be, however, that each perithecium is the result of a sexual act; in the latter case the single perithecium would be the homologue of the *Peziza* cup, while in the former the whole receptacle of *Claviceps* would be homologous to the receptacle of *Peziza*.

386.—As a second illustration of the plants of this order, the Black Knot (*Sphœria morbosa*) which attacks the plum and cherry may be taken.* In the spring the hyphæ, which the previous year penetrated the young bark, multiply greatly, and finally break through the bark, and "form a dense pseudo-parenchymatous tissue." The knot-like mass grows rapidly, and when full sized is usually from two or three to ten or fifteen centimetres long (8 or 1.2 to 4. or 6. in.), and from one to three centimetres in thickness (.4 to 1.2 in.); it is solid and but slightly yielding, and is composed of hyphæ intermingled with an abnormal development of the phloëm parenchyma of the host plant; bast fibres and modified vessels of the wood also occur. Externally the knot is at this stage of a "very dark brownish-green color," and has a velvety appearance, which is due to the fact that its surface is covered with myriads of short, jointed, vertical hyphæ, each of which bears one, two, or more ovate pointed conidia (Fig. 200, 1). The conidia fall off readily, and doubtless are important agents in multiplying the number of these parasitic growths; they are produced until the latter part of summer, when the hypha branches which bear them shrivel up and disappear.

387.—During the latter part of summer perithecia are produced; but the asci require the greater part of winter to come to perfection. In February the ascospores are fully ripe. The perithecia at this time are nearly globular in shape, and are situated in minute papillæ (3, Fig. 200); the asci loosely cover the walls of the perithecial cavity, and are intermingled with slender paraphyses (4, Fig. 200). Each

---

* What follows is condensed from a paper on "The Black Knot," by Professor W. G. Farlow, in the *Bulletin of the Bussey Institution*, Vol. I., p. 440 (1876). Three excellent plates accompany the paper.

ascus contains eight ovate ascospores, which are two-parted, as is the case in many other members of this order (5, Fig. 200). The ascospores escape through a pore in the top of the ascus, and in from three to five days begin to germinate by sending out a tube or small hypha; sometimes two or more hyphæ start out from a single ascospore (6, Fig. 200).

388.—Besides the perithecia, there are other cavities found which much resemble them, but which contain other supposed reproductive bodies. In one kind are found the stylospores, which are quadrilocular oval bodies, borne on long stalks (2, Fig. 200); they occur generally in definite

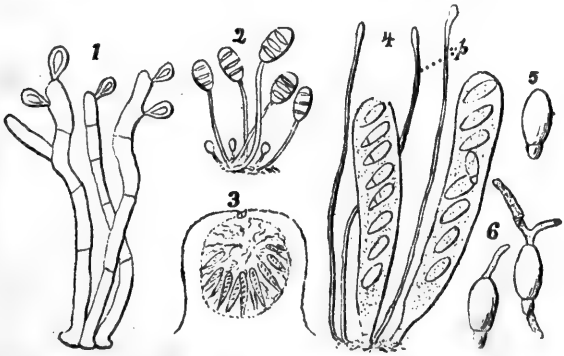


Fig. 200.—Reproductive organs of *Sphæria morbosa.* 1, conidia-bearing hyphæ from a section of the knot on the cherry, made in May; 2, stylospores; 3, outline of a vertical section of a perithecium, made in winter; 4, two asci, with the contained ascospores, enlarged from 3; *p*, paraphyses; 5, a ripe ascospore; 6, two ascospores in process of germination. All much magnified.—After Farlow.

patches on the walls of the globular cavities above mentioned. Their function is unknown; but in all probability they are asexual reproductive bodies. In other perithecium-like cavities slender filaments are produced; these are the spermatia, and the cavities in which they occur are the spermagonia. Still other cavities, much like the preceding, "are lined with short delicate filaments, which end in a minute oval hyaline body;" these small bodies are produced in immense numbers; when they are discharged from the cavities in which they grow, they ooze out in long jelly-like masses. The cavities are called pycnidia, and the small

bodies pycnidio-spores. Neither the spermatia nor the pycnidio-spores have been known to germinate; but from the resemblance of the former to those of *Cucurbitaria, Valsa,* and other genera of this order, which have been seen to germinate,* it is quite certain that they, at least, are reproductive, and that "they are the agents for the dissemination of the species to a great distance," for which they are fitted by their extreme minuteness. In all probability the pycnidio-spores have also a similar function.

389.—No sexual organs have as yet been observed. Doubtless they exist in the dense tissues of the knot, and fertilization probably occurs in the spring or early summer, while the conidia are being produced on the surface of the young knot.

390.—The hyphæ of each year's knot generally penetrate downward some centimetres into the uninjured bark, and remain dormant there until the following spring, when they begin the growth which results in the production of a knot, as described in paragraph 386.

(*a*) The Pyrenomycetes include a large number of exceedingly injurious fungi; they often attack and destroy not only plants, but also insects, upon which their ravages are in many cases very great.

(*b*) The classification is as yet in great confusion.† The principal genus is *Sphæ ia*, which contains many species. *Valsa*, *Diatrype*, and *Hypoxylon* are other important genera.

(*c*) Good specimens of *Claviceps purpurea* may be obtained from almost any rye-field, and more certainly from the isolated bunches of rye growing here and there in many fields. By making repeated examinations soon after the flowering of the rye the conidia may be obtained; and by gathering the sclerotia and burying them in moist sand under a bell-jar, the receptacles may be grown.

(*d*) Specimens of *Sphæria morbosa* for study should be gathered at different times in the season—from early spring to the latter part of the winter following. The first gathered will be necessary to the

---

* Dr. Max Cornu, in "Annales des Sciences Naturelles," Sixth Series, Vol. III., gives the details of his experiments upon germinating the spermatia of many Pyrenomycetes. A translation appeared in "Grevillea," 1877 and 1878, Nos. 36 to 39.

† The student may profitably consult, in studying this difficult order, the finely prepared sets of "North American Fungi," by J. B. Ellis, begun in 1878, and still continuing.

study of the young and forming knot, while the succeeding ones will show first the conidia, and then the forming perithecia and developing asci and ascospores. The last gathered specimens in February will show the fully formed ascospores.

(*e*) Ergot, which occurs on rye and many of the forage grasses, is poisonous, producing gangrenous sores when eaten in considerable quantities. It is used somewhat in medicine.

(*f*) *Xylomites* in the Jurassic, and *Sphæria*, *Phacidium*, *Rhytisma* and other genera, in the Eocene and Miocene, are the fossil representatives of this order.

391.—Order Lichenes. Lichens agree, in all the essentials of their structure, with the two preceding orders, *Helvellaceæ* and *Pyrenomycetes*, and there can no longer be shown any good reasons for not classing them with the latter, under the Ascomycetes.

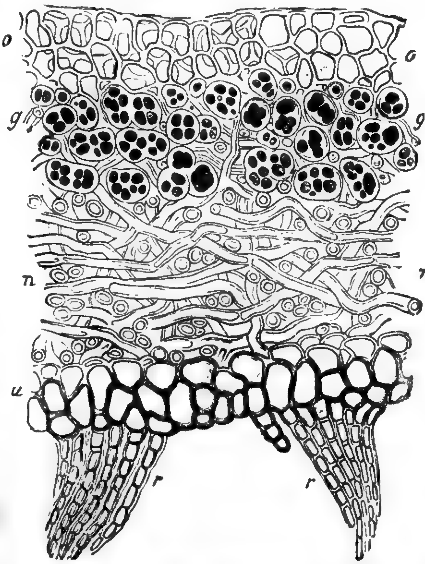


Fig. 201.—Transverse section of the thallus of *Sticta fuliginosa*. *o*, cortical layer of the upper surface; *u*, cortical layer of lower surface; *r*, rhizoids or attaching fibres; *m*, medullary layer, composed of distinct hyphæ, many of which are cut transversely; *g*, layer of green gonidia. Each gonidia group is surrounded by a gelatinous envelope. × 550.—After Sachs.

392.—The tissues of lichens consist of various aggregations of colorless, jointed hyphæ; in general the hyphæ in the cortical portion of the thallus are compacted and developed into a pseudo-parenchyma (*o* and *u*, Fig. 201, and *cc*, *B*, Fig. 202), while in the medullary portion they are distinct (*m*, Fig. 201, and *cm*, *B*, Fig. 202). In all lichens there occur numerous green, blue-green, or brown-green cells, the *gonidia*, which are either scattered through the interior (***homoömerous***), or disposed in one or more distinct layers (***heteromerous***); of the former, *Collema* and *Leptogium* are

examples, while of the latter *Usnea*, *Parmelia* (Fig. 202) and *Sticta* (Fig. 201) may be taken as illustrations.

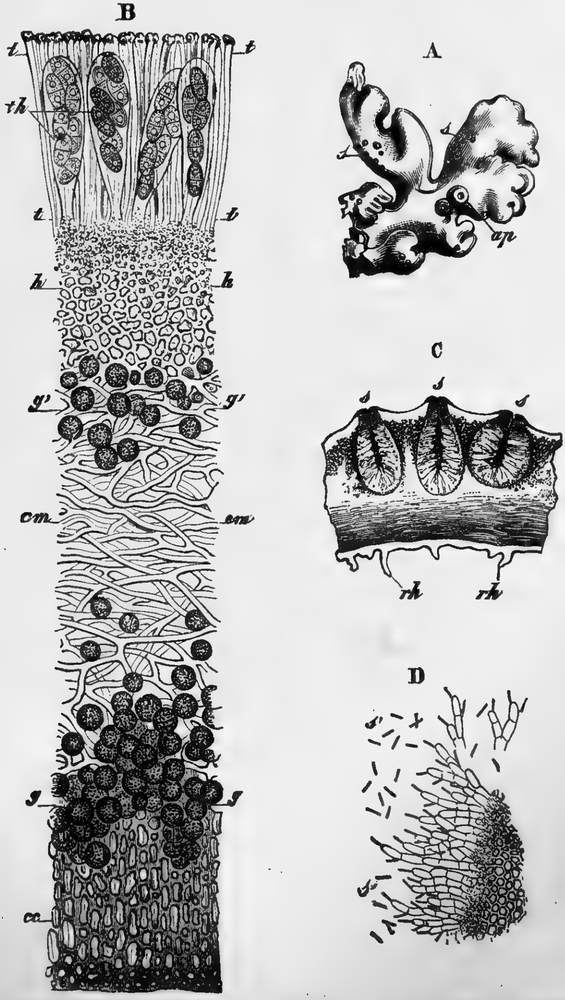


Fig. 202.—*Parmelia aipolia.* *A*, a portion of a thallus with two apothecia, *ap*, and several spermagonia, *s*, *s*. *B*, transverse section of thallus through an apothecium; *cc*, cortical layer of pseudo-parenchyma; *g*, *g'*, gonidial layers; *cm*, medullary layer; *h*, *h*, hypothecium; *t*, *t*, *t*, *t*, the hymenium; *th*, asci (thecæ), with ascospores. *C*, section through three spermagonia, *s*, *s*, *s*; *rh*, *rh*, rhizoids. *D*, sterigmata from the interior of a spermagonium, bearing spermatia, *s'*, *s'*.—After Tulasne.

393.—In their modes of reproduction, also, lichens agree with the before-mentioned orders of the Ascomycetes. Like them, they produce asci, containing ascospores, spermagonia, with their contained spermatia, and one or more other organs whose functions are supposed to be reproductive.

394.—The asci are always developed from the hyphæ, and have no connection whatever with the gonidia. They arise in most (but not all) cases from the hyphæ of the interior of the lichen. It appears that the particular hyphæ which produce asci differ from those which are found elsewhere in the lichen in being of greater diameter and richer in proto-

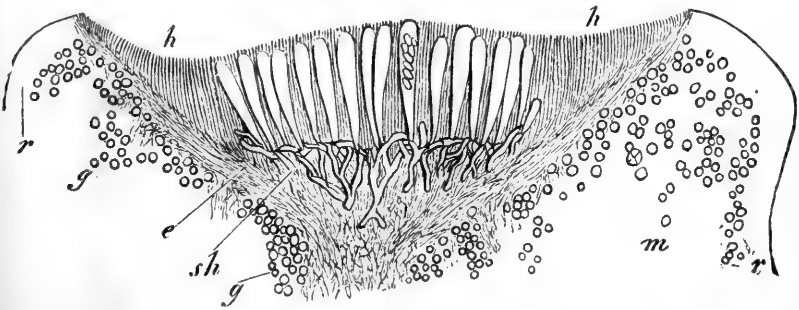


Fig. 203.—Vertical section through the young apothecium of *Lecanora subfusca* (partly diagrammatic); *h, h*, hymenium, composed of (1) paraphyses, which developed from the ordinary hyphæ, and (2) the young asci in various stages of development; *sh*, ascophorous hyphæ, from which the asci develop; *e*, excipulum—*i.e.*, the layer of hyphæ upon which, or above which the ascophorous hyphæ are borne; *r, r*, cortical layer of thallus; *m*, medullary portion of thallus; *g*, the gonidia. × 190. —After De Bary.

plasm. The asci are developed from vertical, club-shaped branches, which penetrate between narrow, vertical branches (paraphyses) of the ordinary hyphæ (Fig. 203). In many cases they are collected in a disc-like surface, forming an exposed hymenium (gymnocarpous lichens), while in other cases they are in the interior of cavities (perithecia), whose walls they line (angiocarpous lichens). The ascigerous fructification is in either case technically called an *apothecium*.

395.—The spores arise in the asci exactly as in the case of *Peziza* and other Ascomycetes previously described; that is, they are formed simultaneously by the condensation of the protoplasm about certain points in the interior of the young

ascus (the so-called free cell formation). Usually there is a considerable quantity of the unused protoplasm left over after the ascospores are fully formed (Fig. 204, *a, b, c*). The usual number of ascospores is eight (Figs. 202, 203, 204), although in exceptional genera they range from one or two (*Umbilicaria*) to a hundred or more (*Bactrospora*, and other genera). They are frequently septate, sometimes being divided into two portions—*e.g., Parmelia* (Fig. 202)—or many, as in *Collema Urceolaria*, etc. In the gymnocarpous lichens the ascospores escape directly into the air. and this they generally accomplish with such force as to be projected some millimetres ; in the angiocarpous genera they first escape into the cavity of the perithecium, from which they pass out through an opening in its apex.

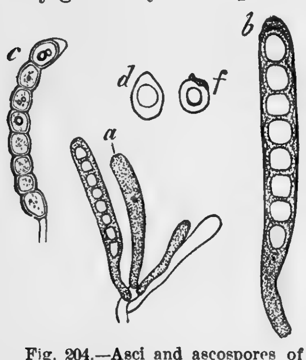


Fig. 204.—Asci and ascospores of *Sphærophorus globiferus*. *a*, young asci in various stages ; *b*, the oldest ascus in *a*, more magnified ; *c*, an ascus nearly ripe ; *d* and *f*, ripe ascospores. × 390, except *b*, × 700.—After De Bary.

396.—In germination the ascospore commonly sends out a germinating tube, which is a growth from the endospore ; it develops directly into a hypha, and becomes branched and septate. Bi- or multilocular ascospores usually send out a germinating tube from each cell. In the genera with very large ascospores—*e.g., Megalospora, Pertusaria*, etc.—the germination takes place in a way somewhat different from that just described. In the endospore a great number of cavities or canals form (*g*, Fig. 205), from each of which there grows out a germinating tube (*d*, Fig. 205) ; these many tubes elongate into hyphæ, and become septate and branched (*f*, Fig. 205).

397.—In addition to the apothecia, with their contained ascospores, there are other organs which contain bodies which are probably reproductive in their nature. The best known of these are the spermagonia (Fig. 202, *A*, *s*, and Fig. 206), which are small cavities, usually found upon the same thallus as the apothecia ; they contain branched

threads (*sterigmata*), which line the inside of the wall (Fig. 202, *D*); upon the sterigmata are borne large numbers of minute cells (the *spermatia*), which fall off and are permitted to escape through the small opening at the apex of the spermagonium. It is unknown whether these germinate or not; some botanists have supposed them to be sexual in their nature—hence their name, spermatia; the recent investigations of Stahl, to be referred to below, seem to indi-

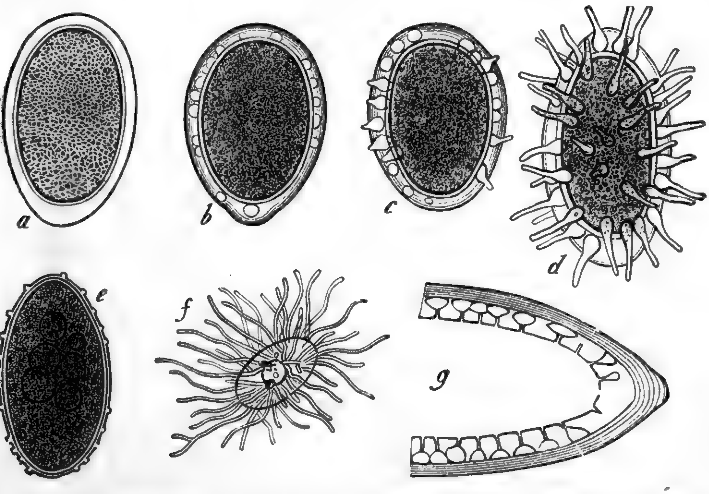


Fig. 205.—Germination of the spores of lichens. *a*, ripe ascospore of *Megalospora affinis*; *b* and *c*, successive stages of germination, seen in optical section; *d*, still later stage of germination, seen in perspective. *e*, beginning of germination of ascospore of *Ochrolechia pallescens*; *f*, the same at a much later stage, showing the many young hyphæ, much less magnified. *g*, half of an ascospore of *Pertusaria ceuthocarpa?* seen in optical section, showing the pores in the endospore through which the hyphæ pass out. The exospore is shaded in the figure. *f* × 190, the others × 390.—After De Bary.

cate the truth of the theory that they are the male sexual elements; on the other hand, their analogies to the similar organs of *Helvellaceæ* and *Pyrenomycetes* point rather to their conidial nature.

Still other cavities (pycnidia) occur, in which spore-like bodies are found, differing in size and other characters from the spermatia.

398.—Until Stahl's researches* showed the existence of sexual organs in *Collema,* they were entirely unknown among lichens. He discovered, deeply imbedded in the tissue of the plant, an organ composed of a spirally coiled hypha-branch, and a vertical septate portion, which rises to, and projects above, the surface; the spirally coiled portion he called the ascogonium, and the vertical portion the trichogyne. The whole he regarded as a species of carpogonium (Fig. 207, *A*, *c*, and *d*). He observed spermatia adhering to the projecting portion of the trichogyne; some of these united themselves to the trichogyne by means of a tube (*C*, Fig. 207). The result of this coalescence was the withering and disappearance of the cells of the trichogyne, and the growth and development of the ascogonium. The latter process takes place as follows: "The cells of the ascogonium first of all increase in size, and then undergo division; as a result of this, the spiral arrangement of the cells becomes less and less conspicuous, for the cells gradually sepa-

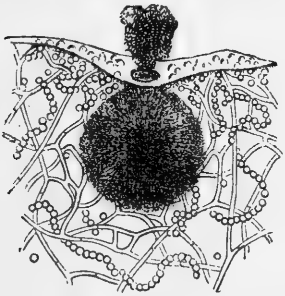


Fig. 206.—Vertical section of a small portion of the thallus of *Collema Jacobæfolium*, showing the colorless branching and jointed hyphæ, the Nostoc-like gonidia, and a spermagonium, from which spermatia are escaping. Magnified.—After Tulasne.

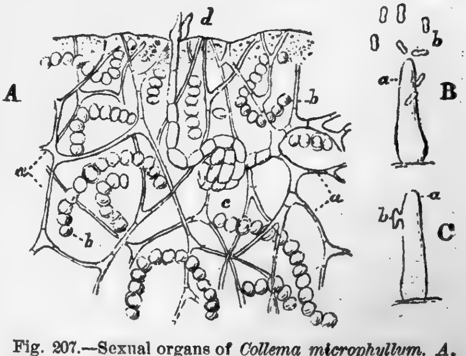


Fig. 207.—Sexual organs of *Collema microphyllum*. *A*, section of thallus; *a*, *a*, hyphæ; *b*, *b*, the Nostoc-like gonidia; *c*, ascogonium; *d*, the exserted trichogyne. *B*, the spermatia, *b*, surrounding the exserted trichogyne, *a*. *C*, coalescence of a spermatium, *b*, with trichogyne, *a*. All the figures magnified, *B* and *C* much more than *A*.—After Stahl.

* "Ueber die Geschlechtliche Fortpflanzung der Collemaceen," 1877 (On the Sexual Organs of the Collemaceæ). A brief synopsis of Stahl's results appeared in the *Qr. Jour. of Mic. Science,* October, 1878.

rate from one another. Whilst these changes have been taking place in the ascogonium, it has become invested by a dense felt-work of hyphæ, formed by the active growth of the hyphæ of the thallus. From this investing layer hyphæ grow inward between the separating coils of the ascogonium, and bear paraphyses, which form the rudimentary hymenium. At the same time outgrowths have been formed from the cells of the ascogonium, which either are asci, or grow into hyphal filaments, which bear asci as lateral branches. The asci, whether derived directly or indirectly from the cells of the ascogonium, come to lie in the hymenium among the paraphyses." Thus the apothecium is partly developed from the carpogonium, and partly from the hyphæ of the thallus, agreeing in this with what is now known to be the mode of formation of the corresponding parts of some, at least, of the *Helvellaceæ.*

Whether there are similar sexual organs in other lichens, is at present unknown ; probably, when discovered, they will be found to bear some resemblance to those of *Collema,* just described ; but it is altogether likely that, instead of fertilization taking place by means of free male elements (spermatia), it will be shown to be more nearly like that now known in *Peziza* or *Ascobolus.*

399.—The Gonidia. The gonidia of lichens are of so much importance that they demand a somewhat extended notice. As above stated (paragraph 392), they are green or greenish cells, or rows of cells, which occur either distributed irregularly through the tissue of the lichen-thallus (the homoömerous lichens), or in different layers or regions (the heteromerous lichens). These green bodies are of different forms in different groups of lichens, while in nearly related species they are often exactly alike. They may consist of isolated cells, or groups of cells, as in most fruticose or foliaceous lichens (*e.g., Parmelia,* Fig. 202, *Sticta,* Fig. 201, *Sphærophorus* and *Usnea,* Fig. 208), while, on the other hand, they may be made up of rows or chains of cells (*e.g., Lecanactis* and *Graphis,* Fig. 209, *Mallotium,* Fig. 210, and *Collema,* Figs. 206 and 207). They are known to reproduce by the division (fission) of their cells, and, in

some cases at least, when free from the lichen-thallus, by the production of zoospores.

Their connection with the hyphæ is sometimes by the prolongation of a short branch from the latter, which passes to each gonidial cell (Fig. 208); in other cases the connection is with one cell of a row, as in *Plectospora,** where the connection may be with the terminal cell of the row, or with any of the intermediate ones; in either case, the cell to which the hypha-branch is attached is considerably larger than the others in the row. Schwendener describes† a con-

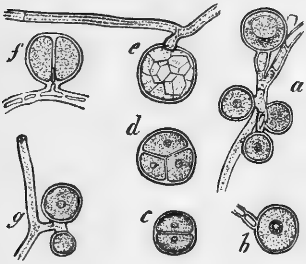


FIG. 208. FIG. 209.

Fig. 208.—Gonidia of different lichens. *a* to *e*, of *Parmelia tiliacea*, showing *a*, *b*, and *e*, the attached hyphæ, × 390; *f*, of *Usnea barbata*, with attached hypha, × 700; *g*, of *Sphærophorus globiferus*, with attached hypha, × 390.—After De Bary and Schwendener.

Fig. 209.—Gonidia. *a*, *a*, of *Lecanactis illecebrosa*; *b*, *b*, of *Graphis scripta*.—After De Bary.

nection which he has seen in certain gelatinous lichens, in which two and three short branches pass off from the same hypha, and unite with the cells of one gonidial chain. Treub‡ confirms Schwendener's statement, saying that he

* See De Bary's "Morphologie und Physiologie der Pilze, Flechten," etc., p. 264.

† "Die Flechten als Parasiten der Algen," 1873.

‡ Dr. Melchior Treub, "Onderzoekingen over de Natuur der Lichenen," 1873.

has "succeeded many times" in finding gonidia so connected to the hyphæ by more than one branch.

400.—With regard to the origin of gonidia, Fries asserts that the hypha-branches swell up at their ends, become globular, and, after a while, filled with green contents.* He, however, does not speak of any observations of his own upon which he bases his statement. Berkeley† likewise regards them as developed from the mycelium, but made no observations which can be considered conclusive. Speerschneider's observations,‡ in 1853 to 1857, along with those of Bayr-

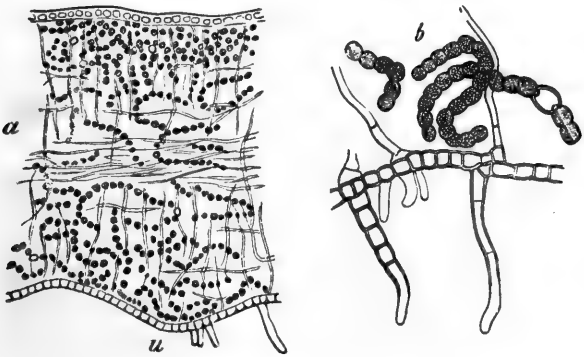


Fig. 210.—*Mallotium* (or *Leptogium*) *Hildenbrandii*. *a*, vertical section through the thallus, *u*, the under side, × 190; *b*, portion of a very thin section near the under side, showing three gonidia chains, two hyphæ, a portion of the lower limitary tissue, and two large and several small hairs, which are organs of attachment, × 390.—After De Bary.

hoffer,§ some years earlier, appear to be, in reality, the ones upon which the view that gonidia develop from the hyphæ depends; their statements appear to have been accepted and repeated by lichenologists without sufficient inquiry. The other errors of observation and interpretation made by these observers render their testimony upon the question of the origin of the gonidia of doubtful value. Schwendener, in

* "Lichenographia Scandinavica," 1871.

† "Introduction to Cryptogamic Botany," 1857.

‡ In *Botanische Zeitung*, 1853, 1854, 1855, 1857.

§ "Einiges über die Lichenen und deren Befruchtung," 1851.

reviewing the subject, affirms that the actual development of a gonidium from the end cell of a hypha has not been observed. Nylander even goes so far as to declare that in no case do the filaments themselves give birth to gonidia, but that they "have their origin in the parenchymatous cortical cells which are observed on the prothallian filaments of germination."*

401.—The recent observations of Dr. Minks,† if confirmed, will put to rest the question as to the origin of gonidia. He studied the small green cells sometimes called microgonidia, and makes the announcement that they originate in the interior of the cells of every portion of the lichen-thallus, viz., the cortical and medullary cells, the paraphyses and young asci, and even the spores and spermatia. The protoplasm in the cells forms an axial column, which becomes broken up into rounded bodies of a pale greenish color; these finally become covered by cell-walls, and afterward escape from the mother-cell as free microgonidia. He asserts that intermediate forms of all degrees are to be met with between microgonidia and gonidia. Dr. Muller, in making similar observations, arrived at the same conclusion‡ as to the origin of the microgonidia.

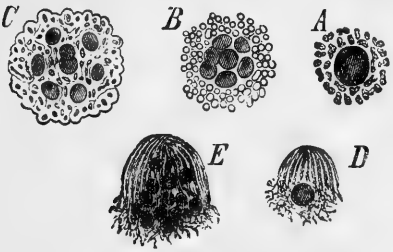


Fig. 211.—Soredia of *Usnea barbata*. *A*, soredium, consisting of one gonidium covered with hyphæ; *B*, of many gonidia formed by division; *C*, the gonidia separated by hyphæ; *D* and *E*, the soredia developing into new lichen plants. × 500.—After Schwendener.

The third view as to the origin of gonidia is so intimately connected with the question of the real nature of the gonidium and its functional relation to the hyphæ, that it can only be explained by taking these into consideration.

---

* In *Flora*, 1877, p. 256, as quoted in *Revue Mycologique*, p. 4, 1879, and in "Grevillea," 1879, p. 91.

† For accounts of these observations see *Flora*, 1878, *Revue Mycologique*, 1879, and *American Journal of Science and Arts*, 1879, p. 254.

‡ *Flora*, 1878.

402.—The gonidia sometimes escape from the thallus of the lichen surrounded with a few hyphæ (Fig. 211); these are called soredia. Under favorable circumstances they may give rise to new lichens, and hence have been looked upon by some as asexual organs of reproduction. Soredia are, however, rather of the nature of buds or gemmæ, which, under certain circumstances, become detached. Their production is, to a certain extent, accidental.

(*a*) 1. **The Nature of Gonidia.** Until recently, the gonidia of lichens have been generally regarded as accessory reproductive bodies. De Bary,* however, in studying the Collemaceæ, and noting the remarkable resemblance between their gonidia and certain algæ, came to the following conclusion: "Either the lichens in question are the perfectly developed states of plants whose imperfectly developed forms have hitherto stood among the algæ as the Nostocaceæ and Chroococcaceæ; or the Nostocaceæ and Chroococcaceæ are typical algæ which assume the form of *Collema, Ephebe*, etc., through certain parasitic Ascomycetes penetrating into them, spreading their mycelium into the continuously growing thallus, and becoming attached to their phycochrome-containing cells." Schwendener,† Reess,‡ and Bornet§ have taken up the second theory in the above alternative, and extended it to all lichens. Schwendener, who first made the definite statement of the theory, holds that every lichen is a colony composed of a parasitic fungus on the one hand, and a number of low algæ on the other; the former, which produces the asci, spermatia, and other reproductive bodies, is nourished by the latter, which constitute the gonidia of the lichen.

A lichen, according to this view, is not an individual plant, but rather a community made up of two kinds of individuals; and the gonidia are only the temporarily imprisoned algæ, which furnish nutriment to the parasitic fungus. The fungus parasite does not differ in any essential character from those of the two higher orders of the Ascomycetes. Leville, in speaking of lichens and the ascomycetous fungi, said,‖ "I find the distinctions to be so trifling, that I have always regretted that these vegetables should not be placed under one head. The paraphyses, thecæ (asci), and spores are identical."

* "Morphologie und Physiologie der Pilze, Flechten, und Myxomyceten," 1865, p. 291.

† Dr. S. Schwendener: "Untersuchungen über den Flechtenthallus," 1868, and "Die Algentypen der Flechtengonidien," 1869.

‡ Professor Max Reess: "Ueber die Entstehung der Flechte Collema glaucescens," etc, 1871.

§ Dr. E. Bornet: "Recherches sur les Gonidies des Lichens," 1873.

‖ A letter to Decaisne, as given in Le Maout and Decaisne's "Traité Générale de Botanique," 1868.

2. Schwendener has shown* that the gonidia may be referred to well-known groups of algæ, some of which belong to the Zygophyta, while others belong to the Protophyta. Thus the gonidia of *Collema, Leptogium* (including *Mallotium*), *Peltigera* and some other genera, are identical with Nostocaceæ; those of *Omphalaria* and others, with Chroococcaceæ; those of *Graphis, Verrucaria*, etc., with Chroolepideæ (related to *Conferva* and *Cladophora*); those of *Usnea, Cladonia, Physcia, Parmelia*, and most higher lichens with Palmellaceæ. The gonidia of some other lichen genera are referred to still other alga groups.

3. When gonidia are dissected out from the lichen-thallus they are capable of independent existence; and there can be no doubt that (as De Bary intimated) many of the forms regarded as algæ are identical with gonidia.† With these facts before us, it can scarcely be doubted that the mode of origin described by Speerschneider and Bayrhoffer is incorrect. There cannot now be shown any good evidence that the gonidia develop from the hyphæ with which they are seen to be in contact. The connection between hyphæ and gonidia is doubtless one which takes place after the origin of the latter. The two remaining views—*i.e.*, Schwendener's and Minks'—agree upon this point, and in both the idea of a genetic connection between gonidium and the hypha-filament in contact with it is rejected. These two theories, however, differ radically in this, that while on the one hand the gonidia are regarded as true lichen-cells, on the other they are held to be algæ belonging to entirely different thallophytic groups.

4. It must at once be evident to any one that the actual relation of the hyphal portion of the lichen to the gonidia is the same whether the origin of the latter be, as asserted by Minks, within the hyphæ, or entirely independent of them, as maintained by Schwendener. Any connection which subsists between these two can be, under the circumstances, of only one kind, namely, that of a greater or less degree of parasitism. It makes no difference to show that the gonidia are derived from the hyphæ themselves, for they are (it is said) set free after their formation in the mother-cell; now any subsequent connection of these green cells with the hyphæ cannot possibly have any other meaning than that the latter derive nourishment from them. The only difference between the two theories may be expressed in this way: according to the one, the imprisoned slaves which furnish nourishment for the hyphal master are members of entirely different groups of the vegetable kingdom; while according to the other, the slaves are the offspring of the hyphal master which imprisons them. In the first the gonidia are

---

* "Die Algentypen der Flechtengonidien," 1869.

† This was long since shown by Itzigsohn—*Botanische Zeitung*, 1854, by Hicks—*Qr. Jour. of Mic. Science*, 1861, and by Famintzin and Baranetsky—*Botanische Zeitung*, 1867; Nylander also arrived at the same conclusion with regard to the gonidia of Collema—*Flora*, 1868.

slaves not at all related to the hyphæ; in the other they are produced by them, and after a brief period of freedom are fastened upon, and compelled to do service for the hyphæ which produced them.

It is impossible to decide between these two theories until further investigations shall determine the truth or falsity of Dr. Minks' statement as to the origin of microgonidia. It must, however, be said, that the view which appears to be most in accord with what we now know of plants, is that taken by Schwendener.

(*b*) 1. **Cultures of lichens** have been made by many observers, especially by Bornet, Reess, and Treub. The latter made an extended series, from which the following details of methods are condensed. Spores may be secured for germination by placing freshly gathered lichens upon plates covered with well-moistened glass slips, and keeping them under a bell-jar for from twelve to twenty-four hours, at the end of which time a number of spores will be found on the slides.

2. The spores may be left upon the slides and allowed to remain in a moist atmosphere, as in a bell-jar. Others may be placed upon very thin pieces of the bark upon which the lichens naturally grow. Still others may be made to grow in the presence of a small quantity of the ash of the same species of lichen.

3. A too copious supply of moisture is unfavorable to the successful germination of the spores. If the conditions are favorable germination will begin in from two to eight days. In about a month after sowing, the protoplasm of the spore becomes in great part used up in the formation and elongation of the germinating filaments. It always happens that the growth of the hyphæ from the spores ceases soon after the exhaustion of the protoplasm, unless the hyphæ come in contact with algæ of the proper kind, or with gonidia.

4. An interesting culture may be made by repeating Bornet's experiment, as follows: He placed on fragments of bark, previously boiled to kill all other germs, and also on pieces of limestone freshly broken, a layer of *Protococcus viridis* scraped off of a damp wall, and to this added the spores of *Theloschis'es parietinus.* In about a fortnight the hyphæ were seen to be large and ramified; wherever they came in contact with cells of the *Protococcus* they adhered either directly or by means of lateral branches. Bornet made at the same time parallel cultures, without, however, bringing the germinating spores into proximity to *Protococcus;* the growth was much less, and in no case did he get any evidence that the hyphæ themselves formed gonidia.

5. Treub modified Bornet's culture by using, in some of his experiments, the artificially isolated gonidia of one species of lichen—for example, of some species of *Ramalina*—and the spores of a different one, as *Theloschistes parietinus.* He also used glass slides for his cultures, whether with gonidia or free algæ, taking the precaution, however, to allow the drop of water in which the spores and gonidia were placed

to completely evaporate before placing in the moist chamber. By taking precautions to keep out moulds, by supplying the moist chamber with air passed through one or two plugs of cotton-wool, he succeeded in continuing the growth of the hyphæ for three months, at the end of which time the algæ were surrounded by a good number of branches

FIG. 212.

FIG. 213.

Fig. 212.—*Usnea barbata*, nat. size. *a*, *a*, apothecia ; *f*, disk by which it is attached to the bark of a tree.—After Sachs.

Fig. 213.—*Sticta pulmonacea*, nat. size. *a*, *a*, apothecia.—After Sachs.

of the hyphæ, many of which had firmly attached themselves to the cells of the algæ.

(*c*) The classification of lichens is by no means settled.

The arrangement which is followed in this country is that of Professor Tuckerman.* He divides the order into five tribes, as follows:

TRIBE I. PARMELIACEI.

Apothecia rounded, open, scutelliform, contained in a thalline exciple.

Family 1. Usneei. *Roccella, Ramalina, Dactylina, Cetraria, Evernia, Usnea* (Fig. 212), *Alectoria. Roccella tinctoria* and other species of the genus furnish the dye known as orchil, and chemical test "litmus." *Cetraria islandica*, the Iceland moss, is used both as a food and a medi-

* Edw. Tuckerman : "Genera Lichenum ; An Arrangement of North American Lichens," 1872, and "Synopsis of N. A. Lichens," 1882.

cine. Species of *Evernia* are sometimes used for furnishing yellow dyes.

Family 2. Parmeliei. *Speerschneidera, Theloschistes, Parmelia* (Fig. 202), *Physcia, Pyxine.* From *Parmelia parietina* fine dyes have been obtained.

Family 3. Umbilicariei. *Umbilicaria.*

Family 4. Peltigerei. *Sticta* (Fig. 213), *Nephroma, Peltigera, Solorina. Sticta pulmonacea* was formerly used in medicine, but it has fallen into disuse, excepting with quacks.

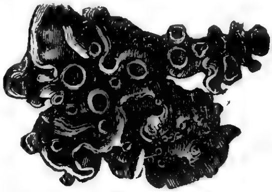


Fig. 214.—*Collema pulposum*, slightly magnified, showing the apothecia.—After Sachs.

Family 5. Pannariei. *Heppia, Pannaria.*

Family 6. Collemei. *Ephebe, Lichina, Synalissa, Omphalaria, Collema* (Fig. 214), *Leptogium, Hydrothyria.*

Family 7. Lecanorei. *Placodium, Lecanora, Rinodina, Pertusaria* (Fig. 215, *C*), *Conotrema, Dirina, Gyalecta, Urceolaria, Thelotrema, Gyrostomum. Lecanora tartarea* furnishes a dye, and *L. esculenta*, of Asia Minor, supplies a valuable food; it is sometimes "carried up by whirlwinds and deposited after traversing the air for many miles, giving rise to stories of the miraculous descent of food. A few years since, in a time of great scarcity at Erzeroum, a shower of these lichens fell most opportunely, to the great relief of the inhabitants."*

Fig. 215.—*A*, *Graphis elegans* on a piece of a twig of the holly; *B*, the same slightly magnified; *C*, *Pertusaria Wulfeni*, slightly magnified, on a piece of old wood.—After Sachs.

TRIBE II. LECIDEACEI.

Apothecia rounded, open, patelliform, contained in a proper exciple.

Family 1. Cladoniei. *Stereocaulon, Pilophorus, Cladonia. Cladonia rangiferina* is the "Reindeer moss" of the Arctic regions; it furnishes a valuable food to the reindeer.

* Berkeley: "Introduction to Cryptogamic Botany," p. 383.

Family 2. Cœnogoniei. *Cœnogonium.*
Family 3. Lecideei. *Bæomyces, Biatora, Heterothecium, Lecidea, Buellia.*

TRIBE III. GRAPHIDACEI.

Apothecia of various forms, frequently lirelliform, in a proper exciple. Thallus crustaceous.
Family 1. Lecanactidei. *Lecanactis, Platygrapha, Melaspilea.*
Family 2. Opegraphei. *Opegrapha, Xylographa, Graphis* (Fig. 215, *A*).
Family 3. Glyphidei. *Chiodecton, Glyphis.*
Family 4. Arthoniei. *Arthonia, Mycoporum.*

TRIBE IV. CALICIACEI.

Apothecia turbinate-lentiform or globose, frequently stipitate, margined by a proper exciple, the disk breaking up into naked spores, which form a compact mass.
Family 1. Sphærophorei. *Sphærophorus, Acroscyphus.*
Family 2. Caliciei. *Acolium, Calicium, Coniocybe.*

TRIBE V. VERRUCARIACEI.

Apothecia globose, in a proper exciple, becoming pertuse with a pore.
Family 1. Endocarpei. *Endocarpon, Normandina.*
Family 2. Verrucariei. *Segestria, Staurothele, Trypethelium, Sagedia, Verrucaria, Pyrenula, Pyrenastrum, Strigula.*
(*d*) Fossil lichens are extremely rare, only a few Tertiary species of modern genera being recorded.

403.—Order Uredineæ.—The Uredineæ are related to the foregoing orders of the Ascomycetes, and probably should be grouped with them. They are all parasitic in habit, and the vegetative portions of the plant-body are greatly reduced, leaving but little more than the organs of reproduction. Their life-history is but imperfectly known, and nothing is yet known as to their sexual organs. They are generally polymorphic—that is, they assume, in their production of various kinds of spores, such apparently distinct forms, that these have frequently been mistaken for distinct plants.

404.—So far as made out, the life-history of the Uredineæ appears to be about as follows: In the spring there appear in the tissues of the leaves of various plants dense masses of

hyphæ, which penetrate between the cells, causing the leaves to become usually much thickened and distorted in those parts which are infested with the parasitic growths. Oc-

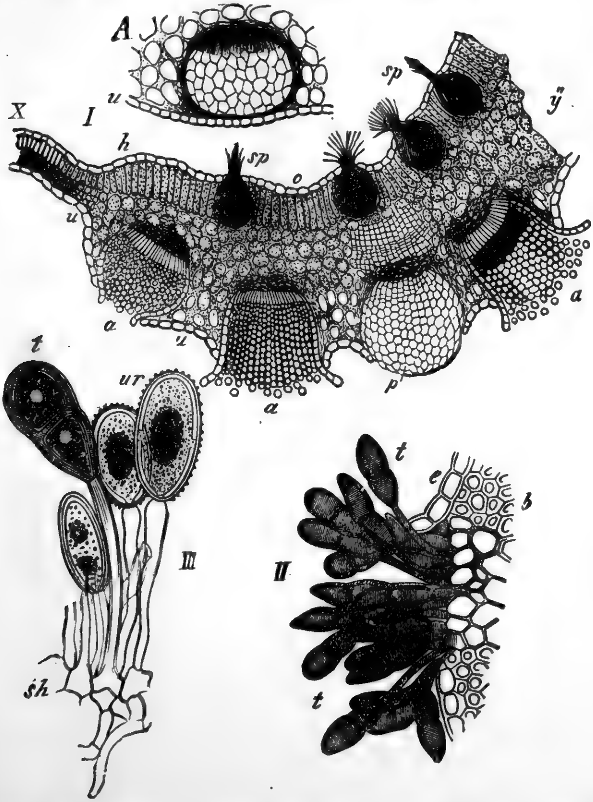


Fig. 216.—Several stages of *Puccinia graminis*. *A*, part of a vertical section of a leaf of the Barberry (*Berberis vulgaris*), with a young unopened æcidium fruit; *u*, epidermis. *I.*, section of a Barberry leaf, natural thickness at *X*, greatly thickened from *h* toward *y*; *u*, epidermis of the under surface; *o*, of the upper surface; *p*, unopened æcidium fruit; *a*, *a*, *a*, opened æcidium fruits; *sp*, *sp*, spermagonia. *II.*, a mass of teleutospores on a leaf of Couch-grass (*Triticum repens*); *e*, the ruptured epidermis; *b*, sub-epidermal fibres of the grass leaf. *III.*, three uredospores, *ur*, with one teleutospore, *t*; *sh*, sub-hymenial hyphæ. All highly magnified.—*A* and *I.* after Sachs; *II.* and *III.* after De Bary.

casionally these hyphæ are found in other parenchymatous parts besides the leaves, as the petioles, young stems, and even the flowers and fruits. After a short time there form

globular masses, which lie in the parenchyma just beneath the epidermis ; these are composed at the bottom of an hymenium-like layer of sterigmata (shown in Fig. 216, *A* and *I*, as a layer of elongated cells). Each sterigma produces a chain of cells, which are at first many-sided from mutual pressure, but afterward spherical. By their growth these globular masses finally burst through the epidermis (Fig. 216, *I.*, *p*), and soon afterward, by the rupture of the thin investing layer of cells (peridium), they become opened and cup-shaped (Fig. 216, *I.*, *a*, *a*, *a*). The now rounded cells are set free as large yellow conidia (or æcidiospores). At one time this stage was supposed to constitute a distinct plant, and it received the generic name of *Æcidium*, hence it is still known as the æcidium stage.

In many (if not all) cases there is a second kind of reproductive organ present, resembling in some respects the æcidium fruits just described. These are smaller flask-shaped cavities, which are filled with slender hair-like filaments (Fig. 216, *I.*, *sp*, *sp*) ; these are the spermagonia, and they produce, by the breaking up of the filaments, numerous exceedingly small oblong bodies, the spermatia. The function of these is not known ; at one time it was supposed that they were the male reproductive bodies, but it is very doubtful whether they are of this nature.

405.—The conidia (æcidiospores), when they fall upon the leaves of the proper host plant, germinate, and penetrate the stomata, thus reaching the leaf parenchyma, where a dense mycelium is formed. Upon this are formed, within a short time, stalked spores (uredospores, Fig. 216, *III.*, *ur*) ; these finally burst through the epidermis, and form orange-colored spots upon the leaves. The uredospores fall off very easily, and germinate quickly, giving rise immediately to another mycelium (Fig. 217, *D*), which produces uredospores, which may, in turn, give rise to new mycelium, and so on indefinitely. The function of the uredospores is clearly the quick reproduction of the fungus.

406.—After the production of uredospores has continued for some time, the same mycelium gives rise to stalked, thick-

walled bodies (*teleutospores*,* or pseudo-spores), which are one, two, three, or many-celled (Fig. 216, *III.*, *t*). Like the uredospores, the teleutospores are produced beneath the

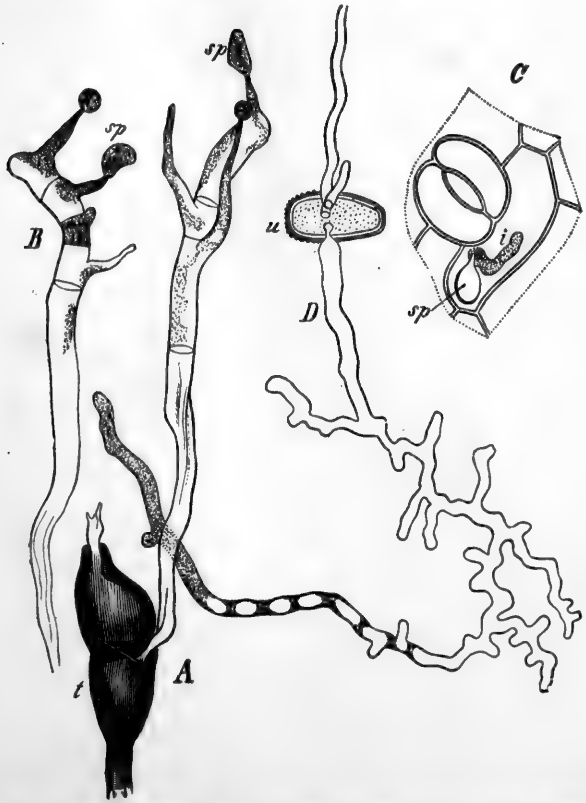


Fig. 217.—*Puccinia graminis.* *A*, germinating teleutospore, *t*, with promycelium forming the sporidia, *sp*. *B*, similar promycelium, with sporidia. *C*, a sporidium, *sp*, germinating on a piece of the under side of a leaf of the Barberry, the mycelium, *i*, penetrating the epidermis. *D*, a germinating uredospore, *u*, fourteen hours after being placed on the leaf of a grass, forming a branched mycelium. Highly magnified. —After De Bary.

epidermis of their hosts, which in their growth they burst through, and appear as small rounded clusters (*sori*), or more

---

* From the Greek τελευτή, end; so named because it is generally the last reproductive body of these fungi produced in the season.

or less elongated lines. In color they are almost invariably brown or nearly black, in marked contrast to the reddish yellow (orange) uredospores. In some cases they are produced early in the season, but in the greater number of cases they appear in the autumn, and then remain through the winter upon the dead stems of their host plants. The following spring the teleutospores germinate by sending out a jointed filament (the *promycelium*) from each cell; this grows to several times the length of the teleutospore, and then sends out a few lateral branches, each of which bears a small terminal cell, a sporidium (Fig. 217, *A* and *B*, and Fig. 218). The sporidia are extremely minute, and, as a consequence, are carried about from place to place in the wind with great ease. When they fall upon the proper plant, each sporidium sends out a minute filament, which perforates the epidermis-cells, and from these passes into the leaf parenchyma, where it develops into a mycelium (Fig. 217, *C*). From this last mycelium the æcidium fruits first described develop.

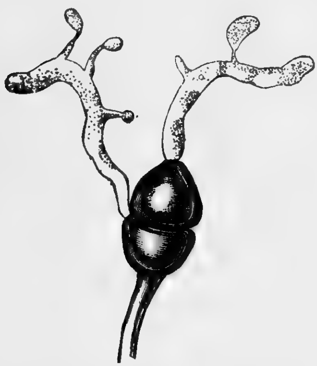


Fig. 218.—Germinating teleutospore of *Puccinia Moliniæ*, showing promycelium and sporidia.—After Tulasne.

(*a*) The life-cycle, as above given, is apparently abridged in some of the Uredineæ. The æcidium and uredo stages are merged into one, or either the first or second is entirely wanting. This appears to be the case in *Phragmidium*, *Gymnosporangium*, *Melampsora*, etc.

(*b*) With most of the species it happens that the æcidiospores (conidia) develop upon one host, and the uredospores and teleutospores upon another. This alternation, which is termed by De Bary *heterœcism*, has added very much to the difficulty of the study of these fungi, and possibly the apparent abridgement of the life-cycle above mentioned may in some instances be only an obscure heterœcism.

(*c*) Thus far the sexual organs have not been discovered; Sachs* argues that they must precede the æcidiospores, and that the æcidium fruit is in all probability the result of a sexual act. He bases his argument upon the law that the reproductive organs of most complex struc-

* "Lehrbuch der Botanik," 4te Auflage, 1874, p. 331.

ture follow or proceed from a sexual act; and maintains that the æcidium fruit is more complex in structure than any of the others. He further says, "The æcidium fruit corresponds, then, to the perithecium of the Ascomycetes, the æcidiospores to the ascospores; and the uredospores and teleutospores are evidently different forms of conidia." It is very doubtful, however, whether future investigations will prove the correctness of Sachs' surmise. It is much more probable that the teleutospores result from a sexual act, and that they are to be compared to the asci of the Ascomycetes. The teleutospores are possibly reduced asci, containing one or more large ascospores; in some cases—*e.g.*, in *Puccinia Helianthi*—an outer investing membrane can be distinguished after treatment with potassic hydrate, while in *Puccinia* (*Uropyxis*) *Amorphæ* there is "a deciduous outer coat,"* which contains the double spore, and (when moistened) a mass of jelly. In both these cases the membranous covering closely resembles an ascus which fits closely over its contained double spore. In the genus *Phragmidium* (Fig. 220), especially in young teleutospores, the resemblance to asci and ascospores is still more striking; the so-called "cells" of the teleutospore originate as so many separate masses in the interior of a large ascus-like membrane (Fig. 219); in their further development the cells become large, and at last fill up the whole cavity, and then have the appearance of Fig. 220.

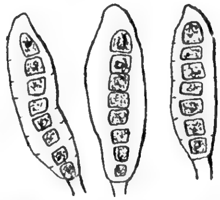


Fig. 219.—Young teleutospores of *Phragmidium mucronatum*, showing the angular masses which eventually develop into the cells of the mature teleutospore. Highly magnified.

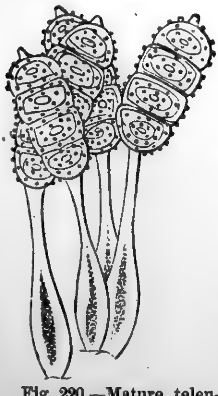


Fig. 220.—Mature teleutospores of *Phragmidium bulbosum*. Highly magnified.—After Cooke.

The resemblance of the teleutospores to reduced asci is close enough to make it probable that sexual organs resembling those of Ascomycetes will be found to precede them. This is rendered the more probable from the resemblance of æcidiospores, spermatia, and uredospores to the conidia, spermatia, and stylospores of various Ascomycetous fungi.†

(*d*) The principal genera in this order are *Uromyces* and *Melampsora* with one-celled teleutospores, *Puccinia* and *Gymnosporangium*, with two cells, and *Phragmidium* (Fig. 220) with many cells. Many species are known, there being in the genus *Puc*

* So described by Berkeley: "Introduction to Cryptogamic Botany," 1857, p. 325.

† Some of these resemblances were pointed out many years ago by

cinia alone from forty to fifty species in the United States. They attack many species of Phanerogams, but are scarcely known as parasites upon Cryptogams. The first stage was long known as the genus *Æcidium*, and under this many supposed species were described, and this is still the case in all English systematic works ; in the same way the second stage gave rise to the supposed genera, *Uredo*, *Trichobasis*, etc., and even these are, to a great extent, retained in the ordinary books, although their autonomy was long since disproved.

(*e*) One of the best known species of this order is that which appears upon wheat, oats, and some other cultivated grasses, producing, or rather being, the disease known as *Rust* (*Puccinia graminis*). It appears in the spring upon the leaves of the Barberry, developing there the æcidiospores (conidia), and constituting what for a long time has been known as the Barberry Cluster-Cups, or Barberry Rust (Fig. 216, *A* and *I*.). Later in the season, and usually after the Cluster-Cups have entirely disappeared from the Barberry, the uredo stage begins to make its appearance, first upon the leaves, and then upon the stems of the wheat, oats, etc.; at first it may be detected by the pale yellowish or whitish spots on the leaves ; these mark the places where the uredospores are beginning to form beneath the epidermis. Within a few days the uredospores (Fig. 216, *III.*, *ur*) break through the epidermis and expose long lines of the orange-red spores. By the quick germination of the uredospores, first produced, the fungus is greatly increased, so that frequently the host plant is destroyed before reaching its maturity. This stage is known popularly as the Red Rust of wheat, oats, barley, and other similar grasses. Still later in the season, and usually after the ripening of the host plants, the dark-colored teleutospores (Fig. 216, *II*.) appear in long black lines, sometimes upon the leaves, but more frequently upon the stems, and in ordinary cases upon the uncut part of the stem, viz., the "stubble." This stage is known as the Black Rust. The teleutospores remain upon the dead stems through the winter, and in the following spring germinate and produce sporidia, which give rise to a mycelium in the Barberry leaves (Fig. 217, *A*, *B*, and *C*).

De Bary,† by placing the teleutospores upon young leaves of the Barberry, succeeded in producing the æcidium stage, thus proving Barberry rust to be but a stage of *Puccinia graminis*. Similarly it has been shown that the æcidiospores of Barberry rust will not grow upon Barberry leaves, but that when placed on a leaf of wheat, oats,

---

Frederick Currey. In a paper "On the Affinities of the Uredineæ," presented to the Iowa Academy of Sciences, May, 1878, I pointed out that the structural similarity of Uredineæ and Ascomycetes rendered it probable that the sexual organs of the former preceded the teleutospores. I did not then know of Currey's paper.

† Published in *Monatsber. d. Berl. Acad.*, 1865.

barley, etc., they send out filaments, whcih pass through the stomata, and give rise to a mycelium, which, in about a week, produces uredospores.

(*f*) Uredineæ are easily obtained for study in either the first, second, or third stage. In most species the æcidium stage occurs in spring or early summer, the second in spring or summer, and the third in the autumn ; in some species, however, the teleutospores are produced in the spring, as in *Gymnosporangium* and *Puccinia Anemones.*

(*g*) The sporidia may be obtained by placing pieces of grass stems containing teleutospores in a damp atmosphere, after soaking for a few hours in water. The teleutospores should be freshly taken in most cases from those which have remained upon the stems out-of-doors during the winter.

407.—Order Ustilagineæ. The plants which compose this order are all parasites living in the tissues of Phanerogams. Like the Uredineæ, the Ustilagineæ send their mycelium through the tissues of their hosts, and afterward produce spores in great abundance, which burst through the epidermis. There is, however, in many respects a greater simplicity of structure in the plants of the present order than in the Uredineæ, and this has induced some botanists to doubt their relationship to the last-named order ; however, it appears that the simplicity is one due rather to degradation than to any essential difference in structural plan.

408.—The mycelium of the Ustilagineæ is well defined, and consists of thick-walled, jointed, and branching hyphæ, which are generally of very irregular shape.* The hyphæ grow in the intercellular spaces, as well as within the cell cavities of their hosts. They send out suckers (*haustoria*), which penetrate the adjacent cells much as in the Peronosporeæ ; these are more abundant in the compact tissue of the nodes of stems than in the long-celled tissue of the internodes. The mycelium generally begins its growth when the host plant is quite young, and grows with it, spreading into its branches as they form, until it reaches the place of spore-formation. In perennial plants the mycelium is

* The following account of the Ustilagineæ is based upon an article on this order by Dr. A. Fischer von Waldheim, published in Pringsheim's "Jahrbücher fur Wissen. Bot.," 1869. A translation appeared in the *Transactions of the N. Y. State Agricultural Society*, 1870.

perennial, the fungus reappearing year after year upon the same stems, or upon the new stems grown from the same roots; in annuals it must obtain a foothold in the young plants as they grow in the spring.

409.—The mycelium can be traced in the Monocotyledons often for long distances; thus in the smut of Indian corn (*Ustilago Maydis*), at the time the spores are found in the distorted grains the hyphæ have been detected at all intermediate points down to the lower internodes, and in the smut on wheat (*Ustilago carbo*) they have been observed in every part of the plant, from the root through the stem to the inflorescence. In neither case, however, are the hyphæ to be found in parts through which it is not necessary for them to pass in order to reach the point where the spores are formed; thus they are usually not found in the leaves unless spores are formed in them.

410.—The formation of spores appears to have some relation to the development of the host plant, as they form only in certain parts of the latter, and are not produced until the growth of these parts has taken place. Thus in the Bunt of wheat (*Tilletia caries*) the spores are formed only in the young ovaries; in the anther smut of the *Sileneæ* (*Ustilago antherarum*) the spores are formed in the young anthers; in one of the smuts of the sedges (*Ustilago urceolorum*) they form on the upper surface of the ovary, and in the smut of wheat, oats, etc., in the young flowers. In cases like these it is evident that the time of spore-formation is dependent upon the development of the flowers of their host; and if these are earlier or later in their appearance, the spore-formation will vary accordingly. In the smut of Indian corn (*Ustilago Maydis*), on the other hand, the spore-formation may take place in other parts of the plant, as well as in the ovary; thus it not infrequently makes its appearance upon the stems, and even upon the leaves. In *Ustilago hypogæa* the spores are produced underground upon the root of the host plant (*Linaria spuria*), and in *Ustilago marina*, in the tissues of *Scirpus parvulus*, under water; with these two exceptions, the spore-formation always takes place in parts above ground.

411.—Immediately preceding the formation of spores the hyphæ give rise to many branches, which differ much in appearance from the ordinary ones. This takes place in those parts of the host plant where the spores are afterward produced. These spore-forming hyphæ are thicker than the vegetative ones, and are more gelatinous; they are more or less granular, and they sometimes contain oil globules.

412.—The spores are formed in *Tilletia caries* by little lateral branches budding out upon the spore-forming hyphæ, and acquiring a pear-shaped outline; they become thicker and more spherical, and each eventually secretes a dark, thick wall (Fig. 224, *k'* and *k*). When mature, the spores become free by the drying up of the attaching pedicel. In *Ustilago* the spore-forming hyphæ break up their contents into spores, and in some cases—as, for example, in *Ustilago Maydis*—the process much resembles the formation of ascospores in asci (Fig. 221). It frequently happens that the spore-forming hyphæ fuse together on account of the gelatinous nature of their envelopes; when this takes place, the spores are formed in very irregular masses (Fig. 222, *b*).

In *Sorisporium Saponariæ* this fusing takes place to so great an extent that the real nature of the process is greatly obscured. The spore-forming hyphæ, which are very abundant, become curved at their extremities, and many of these twist themselves into a little ball, and are fused into a single gelatinous body, which eventually becomes a mass of spores. The real nature of the spore-formation is probably indicated by the "solitary spores," which appear singly upon those spore-forming hyphæ which do not compact themselves into balls; in these, the resemblance to asci containing single ascospores is striking (Fig. 223).

413.—The spores, when ripe, have a double wall. The outer—the epispore—is thick, usually brown or black, sometimes smooth, but frequently more or less rough by projections, or marked by reticulations (Fig. 224, *e*). The inner wall—the endospore—is a delicate colorless membrane, which protrudes through the ruptured epispore in germination.

414.—The germination of the spores has been made out

for a few species only.* In all which have been examined the spore sends out a promycelium, which is generally short and jointed, and upon this several sporidia are produced, much as in the Uredineæ. In *Tilletia caries* the promycelium produces a tuft of slender branches (Fig. 224, *h*), which

FIG. 221.

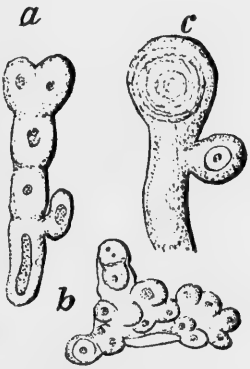


FIG. 222.

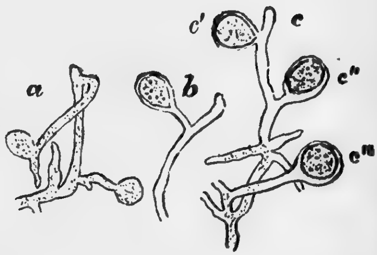


FIG. 223.

Fig. 221.—Spore-formation in *Ustilago Maydis*. *a*, the end of a spore-forming hypha containing a row of young spores; *b*, another spore-forming hypha, containing two young spores; *c*, a spore nearly ripe, still surrounded by the gelatinous membrane of the hypha. × 1800.—After Fischer von Waldheim.

Fig. 222.—Spore-formation in *Ustilago antherarum*. *a*, an isolated gelatinous hypha, with the contents distinctly breaking up—at the lower end a portion not yet broken up; *b*, a number of gelatinous hyphæ fused into an irregular mass, showing the formation of many spores; *c*, a spore nearly ripe, still surrounded by the gelatinous hypha membrane, also a young spore upon a lateral branch. *a* and *c* × 1800; *b* × 900.—After Fischer von Waldheim.

Fig. 223.—Formation of "solitary spores" in *Sorisporium Saponariæ*. *a*, hyphæ with two young spores; *b*, a spore at a later stage; *c*, hyphæ with spores in different stages of development; at *c'* a thin wall has formed around the contained protoplasm as in *b*; at *c''* the wall is much thicker, and at *c'''* it is still thicker. × 300.—After De Bary.

have been seen to unite laterally by a kind of conjugation (not, however, of a sexual nature, in all probability); from these branches (called by some writers "secondary spores")†

* According to Fischer von Waldheim, the germination of the following species is known, viz., *Tilletia caries, T. Lolii, Ustilago antherarum, U. flosculorum, U. carbo, U. destruens, U. Maydis, U. receptaculorum, U. longissima, U. Vaillantii, Urocystis pompholygodes. Uroc. occulta.*

† De Bary calls these branches sporidia, and what are here called sporidia, he calls secondary sporidia.

there grow out small sporidia, which germinate by sending out a slender hypha; when this hypha comes in contact with the proper host plant, it penetrates the walls of its

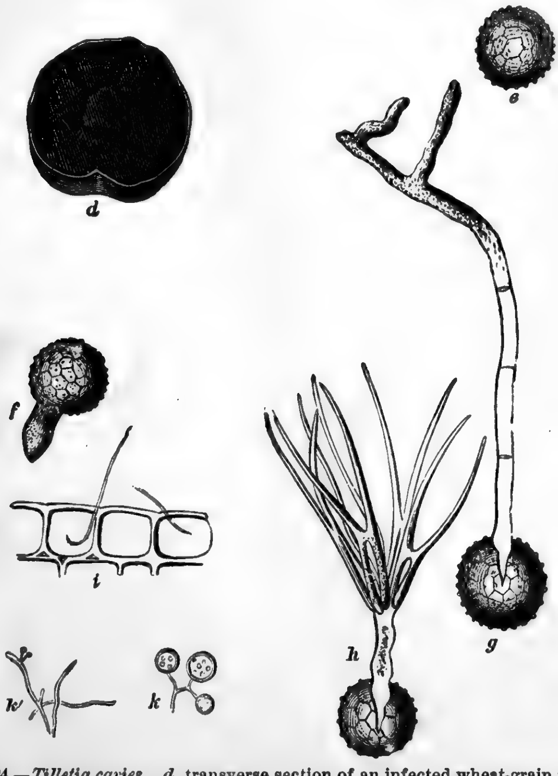


Fig. 224.—*Tilletia caries.* *d*, transverse section of an infected wheat-grain; *e*, ripe spore; *f*, the first stage of germination; *g*, the formation of a branching promycelium, with granular protoplasm in its upper end; *h*, the formation of slender branches which unite by a kind of conjugation; the ends of these branches give rise somewhat later to very small sporidia, and when these germinate very slender hyphæ are produced, which penetrate the epidermis as at *i*; *k'*, mycelium from the young ovary of the wheat—two small lateral branches are shown, from which spores will develop; *k*, spores more fully developed.—*d*, after Œrsted; *e–h*, after Tulasne, × 460; *i–k*, after Kuhn, × 300.

cells, and thus gains admittance to its interior, where it produces a new mycelium* (Fig. 224, *i*). In *Ustilago carbo* the

* This is upon the authority of Kuhn: "Krankheiten der Culturgewächse," 1859. There are some doubts as to the correctness of his observations, and they have not been confirmed by any one.

promycelium branches less frequently, and generally produces from three to four sporidia. In no other case than *Tilletia caries* is the mode of entrance of the fungus into the host plant known.

415.—No sexual organs have yet been discovered. They are probably to be looked for just preceding the formation of the spore-bearing hyphæ. The uniting of the hypha-branches in the germination of the spores of *Tilletia caries* (Fig. 224, *h*) has probably no sexual significance.

(*a*) In the study of the mycelium of the Ustilagineæ, the hyphæ may be made more distinct in thin sections of the host plant by the application of a solution of potassic hydrate. A similar effect is produced by treating the specimen for some hours with thinned glycerine.

(*b*) In the study of the spore development, the specimens must be examined in very early stages of the growth of the fungus. This can generally be done in the case of those species which affect the Gramineæ, by taking the affected "suckers" or lateral branches of the host plant, after the spores are pretty well advanced on the main stem.

(*c*) Upon the application of a solution of iodine, the contents of the young spores become yellow, indicating their protoplasmic nature; treated with Schultz's solution, the contents become brownish yellow. The gelatinous membrane is not colored by the last-named reagent, showing that it is not cellulose; but when treated with a solution of potassic hydrate, it is colored yellow, and in sulphuric acid it is dissolved.

(*d*) The ripe spores frequently require to be treated with reagents to bring out their structure. The endospore may be rendered visible by the application of sulphuric acid which makes the epispore more transparent; in concentrated sulphuric acid the structure of the epispore is made much plainer; treatment with a solution of potassic hydrate causes the spore to swell up.

(*e*) In the study of the germination of the spores, it is only necessary to place freshly gathered spores in a drop of water, or upon moistened earth, or in an atmosphere kept moist, as under a bell-jar. Germination takes place in the proper temperature (20° to 25° C., or 68° to 77° Fahr.) in from three hours (*Ustilago longissima*) to fifty or sixty (*Tilletia caries*).

(*f*) All attempts thus far to determine experimentally the mode of entrance of the fungus into the tissues of the host plant have failed, with the exception of Kuhn's experiments upon *Tilletia caries*. The recent attempts made by Fischer von Waldheim upon *Ustilago carbo* and other species, although made seemingly under the most favorable conditions, utterly failed. He placed fresh spores upon the germinated seeds of oats and barley, upon the entire surface of the rootlets, and

also upon all parts of the young stems and leaves. He even sprinkled the young plants with germinated spores, and in one series of experiments brought the young rootlets in contact with the promycelium and sporidia of the germinating spores. In no case, however, was there any penetration of the fungus into the host plant.

(*g*) The most important genus of the order is *Ustilago*, which contains many species, the most common of which are *U. carbo*, the smut of wheat, oats, barley, and many other grasses; *U. Maydis*, the smut of Indian corn; *U. destruens*, on *Setaria glauca; U. utriculosa*, on species of *Polygonum; U. urceolorum*, on many species of *Carex*. *Tilletia* contains several species, but one of which—*T. caries*—has yet been detected in this country. Of *Urocystis* we have several species, of which *U. cepulæ*, on onions, and *U. pompholygodes*, on Ranunculaceæ, are best known.

§ IV. Class Basidiomycetes.

416.—The plants of this class are among the largest and finest of the fungi. They are mostly saprophytes, provided with an abundant mycelium, which ramifies through the nourishing substratum, and from which there arises afterward a spore-bearing growth, the sporocarp. The spores, of which but one kind is yet certainly known;* are produced upon slender outgrowths from the ends of enlarged cells, termed basidia. The basidia are usually so arranged as to form an hymenium, which is at length external in Hymenomycetes, and internal in most Gasteromycetes.

417.—The sexual organs probably precede the formation of the sporocarp, but they have been but little studied. Œrsted discovered† bodies in *Agaricus variabilis* which, judging from his description, bear a considerable resemblance to the sexual organs of *Peziza*. Whether they occur throughout the class is at present entirely unknown, and as Œrsted's discovery has not been confirmed by other observers, the whole question as to the sexual organs of the Basidiomy-

* Œrsted, in "Kongelige Danske Videnskabernes Selskabs Forhandlinger," Copenhagen, 1865 (translated in *Qr. Jour. Mic. Science*, 1868, p. 18), describes certain little stalked bodies which he found growing upon the mycelium of *Agaricus variabilis*, and which he regards as conidial in their nature. Spermatia also occur on the Tremellini.

† Described in his paper just referred to above.

cetes must be considered as involved in much doubt. Two orders may be readily separated in this class, the Gasteromycetes and the Hymenomycetes.

418.—Order Gasteromycetes. The plants of this order are saprophytes, producing sporocarps which are often of large size, and usually of a more or less globular outline, sometimes long-stalked. The spores are always borne in the interior of more or less regular cavities, and from these they escape by the drying and rupture of the surrounding tissues.

419.—The mycelium of the Gasteromycetes penetrates the substance of decaying wood, and the soil filled with decaying organic matter. It is composed of colorless jointed hyphæ, which usually aggregate themselves into cylindrical root-like masses. After an extended vegetative period, the mycelium forms upon its root-like portions small rounded bodies, the young sporocarps, which increase rapidly in size, and assume the form characteristic of the different genera.

420.—The sporocarps are composed of hyphæ which are much interlaced; in the interior they are more loosely arranged, while externally they form a more or less well-defined limitary tissue, the peridium. In some genera the peridium is composed of two or more layers, as in the Earth-star (*Geaster*). The spores are borne upon hymenial layers which line cavities in the interior of the sporocarp. The basidia upon which the spores are borne are the rounded or elongated terminal cells of hypha-branches; each basidium bears four or more (frequently eight) spores upon the ends of as many small projections (spicules). In *Phallus* and its allies the hymenial cavity lies beneath the double peridium and parallel to its surface; when the spores are formed, by the rapid growth of the axial portion of the sporocarp, the hymenium is carried up through a rent in the apex of the peridium and the spores thus set free. In the Earth-star (*Geaster*), Puff-ball (*Lycoperdon*), and their allies, the hymenial cavities are numerous, of irregular shape, and scattered through the tissue of the sporocarp. The spores are set free by the rupture of the peridium, and the drying of the whole sporocarp, thus reducing its interior hyphæ to a fine powder. In the Puff-ball the single peridium ruptures irregularly, but in the

Earth-star the outer peridium, which is dense, and when dry quite hard, splits from the top into partially separated segments, which recurve and expose the inner more delicate peridium ; the latter ruptures more or less regularly at the top, and thus allows the escape of the spores and dusty broken-up hyphæ.

421.—In the curious little *Crucibulum* and its allies the structure and mode of development are much more complicated. The mycelium, which grows over the surface of decaying wood, forms first a rounded mass of hyphæ in its centre ; this becomes cylindrical, and then undergoes several remarkable changes. In the interwoven hyphæ of the interior, at certain points, there is a very great increase in the number of hyphæ and the density of the tissue ; this takes place with such regularity that several round bodies are formed. The interior of each of these round bodies is at first composed of interwoven hyphæ, but these become mucilaginous, and finally entirely dissolved, forming a central cavity in each mass ; into these cavities hypha-branches now grow, and line them with an hymenial layer of spore-bearing basidia. The round bodies are thus sporangia. While the above-described changes are going on, the tissue lying between the sporangia undergoes conversion into mucilage, and becomes entirely dissolved, leaving only a surrounding wall (the peridium), and slender pedicels composed of hyphæ, which support the sporangia. When these changes are completed, the peridium ruptures at the top and opens out, forming a cup-shaped receptacle, in which the sporangia lie. The sporocarp of *Crucibulum* is thus a much more highly developed organism than that of *Lycoperdon*, although not differing from it in any essential point of structure.

422.—No sexual organs have yet been discovered in the Gasteromycetes, but analogy points to their probable existence upon the mycelium just previous to the first appearance of the spore-bearing portion of the plant (sporocarp).

423.—The mode of germination of the spores is as yet almost entirely unknown.

(*a*) The principal genera of the Gasteromycetes are *Phallus*, which includes the common Stink-horn ; *Lycoperdon* including several species of

Puff-balls, of which the best known is *L. giganteum*, the Giant Puff-ball, an edible species, from ten to thirty cm. in diameter; *Geaster*, the Earth-stars, including several species, and *Crucibulum*, of which *C. vulgare* is very common.

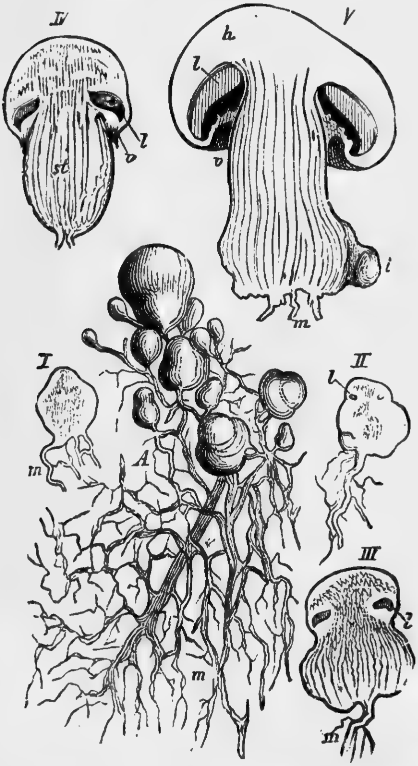


Fig. 225.—Development of *Agaricus campestris*. *A*, underground mycelium (*m*), bearing numerous young sporocarps of various sizes. *I.*, vertical section of a young sporocarp, showing its attachment to the mycelium, *m*. *II.*, vertical section of an older sporocarp, showing the annular opening, *l*. *III.*, the same at a still later stage. *IV.*, young sporocarp, with stalk (*st*); rudimentary gills (*l*), and the beginning of the veil (*v*). *V.*, sporocarp nearly mature; *m*. mycelium; *h*, pileus; *l*, the gills (hymenial lamellæ); *v*, the veil, not yet ruptured; *i*, a very young sporocarp. All natural size.—After Sachs.

(*b*) This order presents no unusual difficulties to the student, and it is one which should receive more attention than it has hitherto. For the study of the structure the specimens should be taken in their earlier stages, as but little can be made out after the hyphæ begin breaking up or dissolving.

424. — Order Hymenomycetes. These plants are doubtless to be regarded as the highest of the chlorophyll-free Carposporeæ. They are not only of considerable size (ranging from one to twenty centimetres, or more, in height), but they present a structural complexity which is so much greater than that of the other orders, that they cannot but be regarded as the highest of the fungi. Like the Gasteromycetes, they produce an abundant mycelium underground, or in the substance of decaying wood; it frequently consists of multitudes of whitish jointed hyphæ, which are loosely interwoven, but in some cases they be-

come densely felted into tough masses five to ten or more millimetres in thickness, and of many centimetres in breadth and length; it frequently also becomes compacted

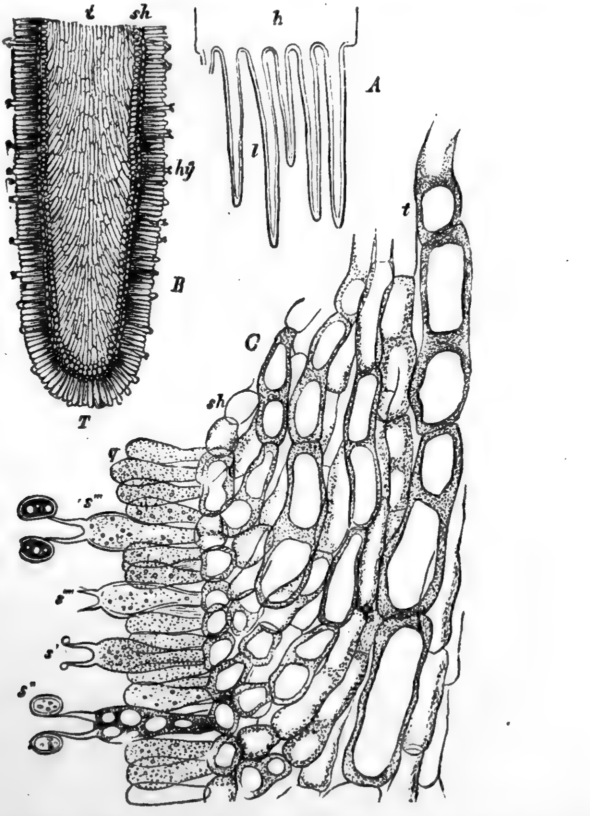


Fig. 226.—*A*, cross-section of the gills or lamellæ (*l*), of *Agaricus campestris*; *h*, portion of pileus; *B*, section of one of the gills, more highly magnified; *t*, the central tissue of the gill (*trama*); *sh*, the sub-hymenial layer of short, rounded cells; *hy*, hymenium. *C*, a small portion of *B*, more highly magnified (× 550); *t*, trama; *sh*, sub-hymenial layer; *q*, young basidia and paraphyses; *s′*, basidium with spores in earliest stage; *s″*, basidium with spores nearly ripe; *s‴*, basidium with ripe spores; *s⁗*, basidium from which the ripe spores have fallen.—After Sachs.

into cylindrical root-like forms (Fig. 225, *A*, *m*). Upon the mycelium there arise, after a longer or shorter period of vegetation, small rounded or oblong masses, the young sporo-

carps. These are composed of parallel vertical hyphæ, which grow upward, and finally bend out laterally, or send out lateral branches at the top, forming the umbrella-shaped pileus common in many of the genera (Fig. 225, *V.*, *h*).

425.—In the common Mushroom (*Agaricus campestris*) the young sporocarp is at first composed of a mass of similar hyphæ (Fig. 225, *I.*); somewhat later, however, an annular opening a little below the apex is visible in a longitudinal section (Fig. 225, *II.*, *l*); this enlarges, and the overlying tissue becomes the pileus (Fig. 225, *III.*, *IV.*, and *V.*, *h*), while that between the opening and the margin of the sporocarp becomes the "veil" (Fig. 225, *IV.* and *V.*, *v*), which finally, by the rapid expansion of the pileus, becomes ruptured, leaving an annular fragment (the ring, or annulus) surrounding the stalk of the fully developed sporocarp. Upon the under surface of the pileus the hyphæ form a great number of thin radiating plates or lamellæ, the so-called gills, and upon their surfaces there develops an extended hymenial layer. The hymenium consists of elongated cells, which are slightly club-shaped, and placed closely side by side perpendicular to the gill surfaces (Fig 226, *B* and *C*). Some of these cells, the basidia, are somewhat longer than the rest, and have, in this species, two, and in most others, four, slender projections, upon which spores (basidiospores) are eventually produced (Fig. 226, *C*, s', s'', s'''). Here and there upon the hymenium there may be found larger bladder-shaped cells, looking like overgrown sterile basidia; their significance is not known, and they have received the name of *Cystidia* (Fig. 226*a*). In some other genera the hymenium, instead of extending over lamellæ, is found lining the walls of vertical pores, as in *Polyporus*, or covering dependent spines, as in *Hydnum*, or spread out on the smooth surface of the sporocarp, as in *Stereum*.

426.—The development of the spores of the Hymenomycetes takes place, according to De Bary,* as follows: The young basidia, which have much the shape of the young asci

---

* "Morphologie und Physiologie der Pilze, Flechten, und Myxomyceten," 1865, p. 111, et seq.

of the Ascomycetes (Fig. 196, *a*, *b*, and *c*), are filled with granular protoplasm; when the projections (*sterigmata*) make their appearance, the protoplasm in the basidium passes into them, and is slightly withdrawn from its lower end. Each sterigma swells at its extremity into a bladder-shaped body, the young spore, and as it enlarges the protoplasm of the basidium is passed into it. By the time the spores are full grown the protoplasm has nearly all disappeared from the basidia. The spores, when ripe, separate themselves from the sterigmata by a transverse partition, and soon fall off.

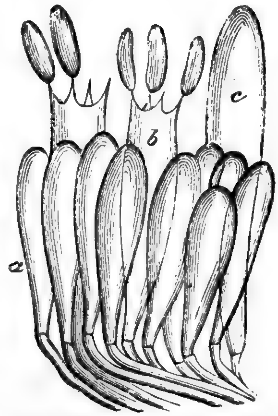


Fig. 226*a*.—A small portion of the hymenium of *Gomphidium*. *a*, sterile cells; *b*, basidia—each with some of the spores attached; *c*, a cystidium.—After De Seynes.

427.—With regard to the germination of the spores but little is known, but in *Coprinus*, according to Van Tieghem,* they give rise to a mycelium, and this is probably the case with all.

428.—The existence of sexual organs in the Hymenomycetes is still involved in much doubt. Œrsted described† long ago certain bodies which he discovered on the mycelium of *Agaricus variabilis* just before the formation of the sporocarp. They are described as consisting of two kinds of cells, viz., (1) single curved, and almost reniform cells, which grow out from the sides of the hyphæ; they are .02 mm. long and about .01 mm. in diameter, and appear to be separated from the hyphæ from which they grow by a septum; (2) very slender filiform cells, which grow out from beneath the former. Œrsted saw (in two instances) a union of these two organs. He came to the conclusion that the sporocarp was the result of a growth due to several such unions—*i.e.*, that the sporocarp was the result not of one, but of several fertilizations.

---

* "Comptes rendus," 1875.

† In the work already cited in the foot-note on p. 323.

For some reason these observations have fallen out of notice, and they still are wanting confirmation. The close resemblance of these organs, as described, to the sexual organs of *Peziza,* renders it probable that they are actually sexual in their nature.

429.—More recently Reess has published the results of his observations upon *Coprinus stercorarius.** He found that upon short lateral branches of the young mycelium many minute bodies (spermatia) are produced; these, after falling off, come in contact with a thick three-celled body (carpogonium ?), which they are supposed to fertilize. Afterward from the basal cell numerous filaments grow out, and eventually give rise to the sporocarp.†

(*a*) In the study of the tissues of the Hymenomycetes young and perfectly fresh specimens are the best; where this is impossible they may be preserved in alcohol, and then studied at leisure. Thin transverse sections of the gills will invariably show basidia and spores.

(*b*) The genera of this order differ not only as to the disposition of the hymenium, but also as to the form of the sporocarp. With respect to the latter, it is symmetrical and stalked, as in the common Mushroom, or unsymmetrical and sessile, as in many species of *Polyporus.* The texture of the sporocarp also varies from soft and deliquescent to hard and durable.

(*c*) The more common genera are *Agaricus,* with several hundred species, *Boletus, Polyporus, Hydnum, Stereum,* and *Clavaria.*

(*d*) Nearly related to the Hymenomycetes, if not indeed to be included with them, are the TREMELLINI, which are gelatinous fungi, upon whose uneven surfaces is spread an hymenial layer, composed of basidia resembling those of Hymenomycetes. Sachs regards these plants as constituting a group related to, but distinct from, Hymenomycetes.

(*e*) Many species are edible and nutritious. *Agaricus campestris,* the Mushroom, is commonly cultivated. Dr. M. A. Curtis found in North

---

* Dr. Max Reess, "Zur Befruchtungsvorgang bei den Basidiomyceten," 1875. Van Tieghem, in "Comptes rendus," 1875, p. 373, makes public the results of his investigations, which are essentially the same as those of Reess, but a few months later he withdraws his statements: "Comptes rendus," 1875, p. 877.

† It is scarcely necessary to refer to the paper by W. G. Smith in "Grevillea," 1875, p. 53, in which he describes a fertilization of the spores by spermatozoids developed by the cystidia. The many other evident errors in the paper make the value of his observations upon the supposed organs of fertilization exceedingly doubtful

Carolina thirty-eight edible species of *Agaricus*, eleven of *Boletus*, nine of *Polyporus*, seven of *Hydnum*, and thirteen of *Clavaria*.

(*f*) *Polyporites Bowmani* of the Carboniferous is the oldest known member of this order. In the Tertiary the modern genera *Lenzites*, *Polyporus*, and *Hydnum* are represented.

§ V. Class Characeæ.

430.—In this small group of chlorophyll-bearing aquatic plants the sexual organs, while still preserving essentially the structure common to other Carposporeæ, present considerable modifications. The female organ consists of a "central cell" or carpogonium (Fig. 227, *c*), which is the terminal one of a row of cells (*a*, *b*, *c*, Fig. 227). From the basal cells there grow out five elongated cells (*d*, *d*, Fig. 227), which take an upward direction and surround the carpogonium; they cohere laterally, so as to form a complete covering. The top of this enveloping sheath becomes modified into a projecting crown of five (or by division ten) more or less divergent cells (*i*, *i*, Fig. 227 *B*; and *c*, Fig. 228, *A*). Finally, the whole envelope becomes twisted, so that each enveloping cell passes spirally around the carpogonium (*A*, Fig. 228).

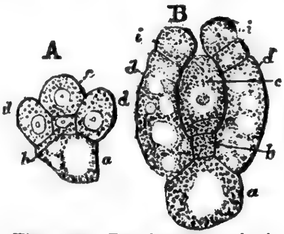


Fig. 227.—Development of the carpogonium of *Nitella flexilis*, shown in vertical section, partly diagrammatic. *A*, very early stage; *c*, the central cell supported upon the small nodal cell, *b*, and the larger cell, *a*; *d*, *d*, rudimentary enveloping cells. *B*, the same somewhat later—the enveloping cells, *d*, *d*, have almost completely enclosed the central cell, *c*; *i*, *i*, cells which form a crown upon the enveloping cells. × 300.—After Sachs.

431.—The male organ, or antheridium, consists of a globular body composed externally of eight spherically triangular cells, called the shields, which are united by their zigzag margins (*a*, Fig. 228, *A*). From the centre of each shield there projects into the cavity of the antheridium a cylindrical cell (*manubrium*), and upon each of these there are borne large numbers (twenty to twenty-five) of long coiled and bent many-celled filaments (*b* and *c*, Fig. 229). Each filament contains from one to two hundred cells,

which are at first filled with granular protoplasm; afterward each cell develops a single spirally coiled spermatozoid. When the antheridium is mature—*i.e.*, when the spermatozoids are fully formed—the shields separate from each other, and thus expose the filaments (Fig. 229). The spermatozoids escape by the rupture of the walls of the filament cells; each consists of a slender spiral thread of protoplasm, thicker at one end than the other, and provided at the more attenuated extremity with two very delicate and greatly elongated cilia (Fig. 229, *d*). By means of these cilia the spermatozoids move through the water with a spiral rotary motion.

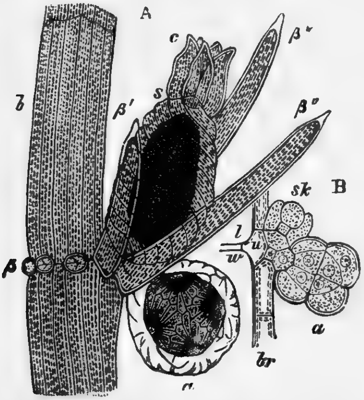


Fig. 228.—Reproductive organs of *Chara fragilis*. *A*, a central portion of a leaf, *b*, with an antheridium, *a*, and a carpogonium, *s*, surrounded by the spirally twisted enveloping cells; *c*, crown of five cells at apex; *β*, sterile lateral leaflets; *β'*, large lateral leaflet near the fruit; *β''*, bracteoles springing from the basal node of the reproductive organs. *B*, a young antheridium, *a*, and a young carpogonium, *sk*; *w*, nodal cell of leaf; *u*, intermediate cell between *w* and the basal node cell of the antheridium; *l*, cavity of the internode of the leaf; *br*, cortical cells of the leaf. *A* × about 33; *B* × 240.—After Sachs.

432.—Fertilization takes place by the entrance of spermatozoids through the orifice between the diverging cells of the crown; they come in contact with the apex of the carpogonium, "where the cell-wall is apparently absent;" as a result of this union, the enveloping cells become thicker walled, hard, and dark-colored, forming a dense and resisting coating to the fully formed carpospore within. The seed-like sporocarp thus formed soon separates itself from the parent plant and falls to the bottom of the water, where it remains until the advent of favorable conditions for germination.

433.—In germination the sporocarp gives rise first to a simple structure consisting of a single row of cells (the proembryo), and from this the more complex sexual plant is developed by the growth of a lateral bud-cell. The sexual

plant is composed of a jointed stem, which bears whorls of leaves at regular intervals. The stem is one-celled in transverse section, as in *Nitella*, or it has a large axial cell, which is surrounded by many long narrow ones, which form a cortical envelope, as in many species of *Chara*. In some species the stem and leaves become incrusted with lime, giving to them a good deal of hardness and brittleness.

(*a*) The class is readily divisible into two orders—Nitelleæ and Chareæ.*

Order Nitelleæ.—In this order the stem and leaves are always naked—*i.e.*, not corticated; the leaves are in whorls of five to eight, and bear large leaflets, which are often many-celled. The sporocarps arise singly or in clusters in the forkings of the leaves, and each has a crown consisting of two superimposed whorls of five cells each.

These delicate plants occur in ponds and streams, and are rarely more than a few centimetres in height. Two genera—*Nitella* and *Tolypella* — are distinguished by the position of the antheridium, which is terminal upon the single node of the primary leaf in the former, while in the latter it is lateral, and the primary leaf has two or three nodes.

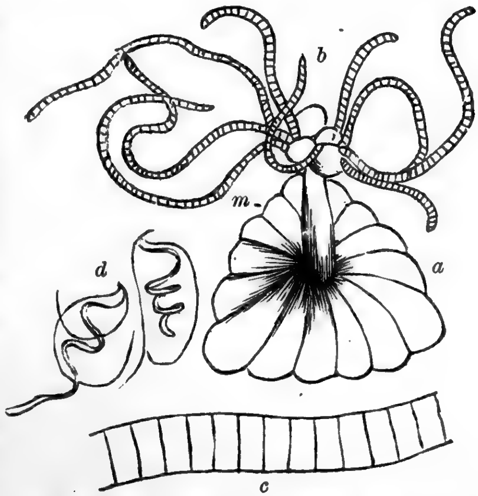


Fig. 229.—*Chara fragilis*. *a*, an isolated shield, *m*, seen from within, with manubrium bearing the filaments, *b*, in which the spermatozoids are developed; *c*, a small portion of one of the filaments, the spermatozoids not shown; *d*, two free spermatozoids. *a* and *b* × 50; *c* and *d* × 300.—After Thuret.

The species of *Nitella* (ten to fifteen of which are American) are ar-

* What follows is mainly from a synopsis of the Characeæ, furnished for this work by Dr. T. F. Allen, the author of "Characeæ Americanæ," now issuing in numbers. Use has also been made of Dr. B. D. Halsted's paper on the "Cassification and Description of the American species of Characeæ," published in *Proc. Boston Soc. Nat. Hist.*, 1879.

ranged under three tribes; our more common species only are given below.

Tribe A.—*Monarthrodactylæ*, with the terminal segments of the leaves one-celled.

N. flexilis, N. translucens, N. gelatinosa.

Tribe B.—*Diarthrodactylæ*, with the ultimate segments of the leaves two-celled.

N. gracilis, N. tenuissima.

Tribe C.—*Polyarthrodactylæ*, with the ultimate segments of the leaves three to six-celled.

N. capillata, N. intricata.

The genus *Tolypella* contains about a dozen known species, most of which are American.

Order Chareæ.—In this order the stem and leaves are sometimes naked, and sometimes corticated; the leaves are in whorls of six to twelve, and their bracts or leaflets are always one-celled. The sporocarps arise upon the upper side of the leaves, and each has a crown of one whorl of five cells.

These plants resemble the Nitelleæ in size and habit. The species are separated into two genera, *Lychnothamnus* and *Chara*. The former has no representatives in America; it may be distinguished by the antheridia being by the side of the carpogonia instead of below them, as is the case in *Chara*.

The species of *Chara* are arranged under three tribes; there are about a dozen representatives in America, the more important of which are here given.

Tribe A.—*Astephanæ*, with no circle of stipules. No American representative.

Tribe B.—*Haplostephanæ*, with a circle of stipules consisting of a simple series of cells.

Ch. coronata, Ch. Hydropitys.

Tribe C.—*Diplostephanæ*, with the stipular ring double.

Ch. fœtida, Ch. fragilis, Ch. gymnopus.

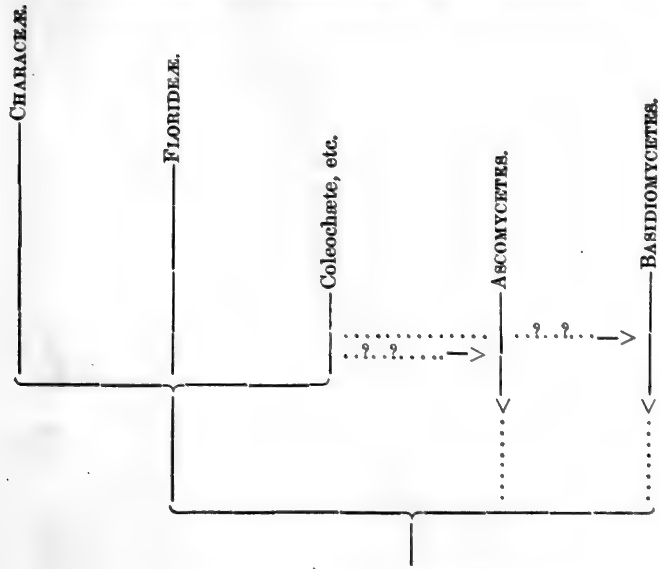
(*b*) The genus *Chara* is a very old one; some species occur in the Secondary (Jurassic) strata, and in the Tertiary (of Europe) they are very abundant, no less than thirty-seven species being recorded by Schimper.* According to Lesquereux † no fossil species of Characeæ have yet been discovered in America, which is a remarkable fact, for at the present time the plants of this group are as abundant here as in Europe, and the sporocarps possess great durability and are likely to be preserved as fossils.

---

* "Traité de Paléontologie Végétale," par W. Ph. Schimper, Paris, 1869–1874.

† "Contributions to the Fossil Flora of the Western Territories; Part II., The Tertiary Flora," by Leo Lesquereux, Washington, 1878.

ARRANGEMENT OF THE CLASSES OF THE CARPOPHYTA.



VI. THE CLASSIFICATION OF THALLOPHYTES.

(1.) The classification of the Thallophytes, outlined in the preceding pages, is essentially that given by Sachs in the fourth edition of his "Lehrbuch." Sachs, however, considered the Protophyta, Zygophyta, Oophyta, and Carpophyta to be Classes, whereas in this book they are raised to Divisions, co-ordinate with Bryophyta, Pteridophyta, and Phanerogamia. It is evident, even from the hasty examination sketched in the preceding pages, that there are three well-marked kinds of reproductive apparatus in the Thallophytes, which are, to a considerable degree, distinct. There are, of course, here and there cases in which one kind merges into another, but this is no more than is to be observed in everything else throughout both the vegetable and animal kingdoms. After making all due allowance for the doubtful cases, the fact yet remains that there are three kinds of reproductive apparatus in the Thallophytes, which are as readily distinguishable as are those of the Cormophyte Divisions, Bryophyta, Pteridophyta, and Phanerogamia.

(2.) Of the differentiation of tissues we know less; but enough is known to warrant the statement that, as in the Divisions of the Cormophytes, there is a progressive increase in complexity as we pass from

the lower to the higher Thallophytes. Thus the Zygophytes, as a rule, are single cells (*Desmidiaceæ* and *Diatomaceæ*), or rows of cells (*Zygnemaceæ*, etc.), of simple structure; the Oophytes are generally single cells of a complex structure (*Cœloblasteæ*), rows of differentiated cells (*Œdogonieæ*), or even tissues, forming structures which have, in some cases, a close approximation to stems and leaves (*Fucaceæ*); the Carpophytes are all multicellular; the lower ones are made up of rows of cells, which are generally united into a plant-body (sporocarp of *Ascomycetes* and *Basidiomycetes*), while in the higher ones there are tissues which form stems and leaves (some *Florideæ* and *Characeæ*).

(3.) It can scarcely be doubted, then, that the three Thallophyte groups Zygophyta, Oophyta, and Carpophyta, are as much entitled to rank as Divisions as are those of the Cormophytes. The Protophyta constitute a provisional group, but while it is very likely that many of the forms now included in it may be placed elsewhere when they are better understood, it is extremely improbable that all will be thus disposed of; it seems more probable that the group may be preserved, very likely in a modified form, as a sort of primary Division.

(4.) The arrangement followed in this book may be made plainer by the subjoined table. The Classes only (printed in SMALL CAPITALS) are given, excepting where, for obvious reasons, it is necessary to particularize more closely (Orders and genera in lower case). The groups on the left are composed of chlorophyll-bearing plants, and are regarded as the proper representatives of the Divisions. The groups on the right hand (printed in *italics*) are composed of plants which are parasitic or saprophytic, and which, as a consequence, show more or less of degradation in their vegetative parts; the absence of chlorophyll here, as in the case of parasitic Phanerogams, is an accompaniment of structural changes in the vegetative parts of the plant, which are always degradational in their nature.

PROTOPHYTA.

1 MYXOMYCETES.

---

2 SCHIZOMYCETES.

.... *Saccharomycetes* (?).

CYANOPHYCEÆ.

ZYGOPHYTA.

Pandorina, etc.

CONJUGATÆ.. *Mucorini*.

OOPHYTA.

Volvox, etc.
ŒDOGONIEÆ.

CŒLOBLASTEÆ.................................. { *Saprolegniaceæ.* / *Peronosporeæ.* }

FUCACEÆ.

CARPOPHYTA.

Coleochæte.
FLORIDEÆ.

....*ASCOMYCETES.*
Uredineæ (?).
Ustilagineæ (?).
....*BASIDIOMYCETES.*

CHARACEÆ.

It will be instructive to compare the foregoing with other attempts at an arrangement of the Thallophytes.

(5.) The arrangement which has long been followed, and which is still in use in most English books, is that which divides the Thallophytes (considered a class) into three orders,* viz.,

1. *Algæ*, aquatic and chlorophyll-bearing.
2. *Fungi*, terrestrial, and destitute of chlorophyll.
3. *Lichenes*, terrestrial, and containing green gonidia.

Berkeley's arrangement† differs from this only in the relative rank of the groups.

Alliance I. Algales (*Algæ*).

Alliance II. Mycetales { Fungales (*Fungi*). / Lichenales (*Lichenes*). }

Algæ have usually been divided into three groups (sometimes called sub-orders), as follows :

1. *Chlorospermeæ*, including all the chlorophyll-bearing plants of the Protophyta and Zygophyta, and all the Oophyta, excepting *Fucaceæ*.
2. *Rhodospermeæ*, nearly equivalent to the *Florideæ*.
3. *Melanospermeæ*, including the *Fucaceæ*, *Phæosporeæ*, and some other plants.

(6.) Fungi are still arranged in most English books in six groups (called orders, sub-orders, or even families), as follows :‡

1. *Ascomycetes*, nearly as in this book.

---

* See Hooker's "Synopsis of the Classes, Sub-classes, Cohorts, and Orders," in the English edition of Le Maout and Decaisne's "General System of Botany," 1872, p. 1023.

† "Introduction to Cryptogamic Botany," 1857, p. 81.

‡ See Berkeley's "Introduction," already cited ; Berkeley's "Outlines of British Fungology," 1860 ; Cooke's "Hand-book of British Fungi," 1871 ; Cooke and Berkeley's "Fungi, their Nature, Influence, and Uses," 1874 ; and Fries' "Systema Mycologicum," 1821.

2. *Physomycetes*, including the *Mucorini* and *Saprolegniaceæ.*

3. *Hyphomycetes*, including *Peronosporeæ, Penicillium*, and many imperfect forms.

4. *Coniomycetes*, including *Uredineæ* and *Ustilagineæ*, and in addition a great number of imperfect stages of Ascomycetes.

5. *Gasteromycetes*, as in this book, with the addition of *Myxomycetes.*

6. *Hymenomycetes*, as in this book, and including the *Tremellini.*

De Bary* arranged Fungi under four groups, as follows :

1. Phycomycetes.
   Saprolegniaceæ. Peronosporeæ. Mucorini.

2. Hypodermiæ.
   Uredineæ. Ustilagineæ.

3. Basidiomycetes.
   Tremellini. Hymenomycetes. Gasteromycetes.

4. Ascomycetes.
   Protomycetes. Tuberaceæ. Onygeneæ. Pyrenomycetes. Discomycetes.

In both the foregoing arrangements of Fungi the Lichens are omitted, they being regarded as of a different nature.

(7.) In 1872 Cohn published† an outline of a classification of the Cryptogams in which the old distinctions between Algæ, Fungi, and Lichens were abandoned. He considered the Thallophytes as constituting a single class, co-ordinate with Bryophyta, Pteridophyta, and Phanerogamia, and divided it into seven orders, and each of these into many families ; the latter are in most cases equivalent to what are called orders in this book. The families in Roman contain chlorophyll, those in italics are chlorophyll-less.

Class Thallophyta.

ORDER I. SCHIZOSPOREÆ.

1. Schizomycetes. 2. Chroococcaceæ. 3. Oscillatoriaceæ. 4. Nostocaceæ. 5. Rivulariaceæ. 6. Scytonemaceæ.

ORDER II. ZYGOSPOREÆ.

1. Diatomaceæ. 2. Desmidiaceæ. 3. Zygnemaceæ. 4. *Mucoraceæ.*

---

* In Streinz: "Nomenclator Fungorum," 1861, p. 722, and also in "Morphologie und Physiologie der Pilze, etc.," 1865, preface, p. 6.

† Ferdinand Cohn, "Conspectus familiarum cryptogamarum secundum methodum naturalum dispositarum," in "Hedwigia," February, 1872.

ORDER III. BASIDIOSPOREÆ.

SECTION 1. HYPODERMIÆ.

1. *Uredinaceæ.* 2. *Ustilaginaceæ.*

SECTION 2. BASIDIOMYCETES.

3. *Tremellaceæ.* 4. *Agaricaceæ* (*Hymenomycetes*). 5. *Lycoperdaceæ* (*Gasteromycetes*).

ORDER IV. ASCOSPOREÆ.

1. *Tuberaceæ.* 2. *Onygenaceæ.* 3. *Erysiphaceæ.* 4. *Sphæriaceæ* (*Pyrenomycetes*). 5. *Helvellaceæ.* 6. *Lichenes* (excluding Collemaceæ).

ORDER V. TETRASPOREÆ (FLORIDEÆ:)

1. Bangiaceæ. 2. Dictyotaceæ. 3. Ceramiaceæ. 4. Nemaliaceæ. 5. Lemaniaceæ. 6. Sphærococcaceæ 7. Melobesiaceæ. 8. Rhodomelaceæ.

ORDER VI. ZOOSPOREÆ.

1. Palmellaceæ. 2. Confervaceæ. 3. Ectocarpeæ. 4. Sphacelariaceæ. 5. Sporochnaceæ. 6. Laminariaceæ.

ORDER VII. OOSPOREÆ.

SECTION 1. LEUCOSPOREÆ.

1. *Chytridiaceæ.* 2. *Peronosporaceæ.* 3. *Saprolegniaceæ.*

SECTION 2. CHLOROSPOREÆ.

4. Volvocaceæ. 5. Siphonaceæ. 6. Sphæropleaceæ. 7. Œdogoniaceæ. 8. Coleochætaceæ.

SECTION 3. PHÆOSPOREÆ.

9. Tilopterideæ. 10. Fucaceæ.

(8.) In 1873 Fischer proposed an arrangement* of the Thallophytes which in many respects is like that of Sachs. Like the latter, Fischer divides the Thallophyta (co-ordinate with Cormophyta) into four classes, composed in each case of chlorophyll-bearing and chlorophyll-free plants, the algæ and fungi. Instead, however, of considering the fungi as degraded forms, he regards them as constituting with the algæ two parallel but entirely distinct genetic lines. The Myxomycetes he places in a third genetic line, nearest to, but still distinct from, the fungi.

---

* Given in Sachs' "Lehrbuch," fourth edition, p. 248. The groups given under each class are of very unequal value.

THALLOPHYTA.

(ALGÆ.)	(FUNGI.)	MYXOMYCETES.

CLASS I.

Without sexual reproduction.

Phycochromaceæ.	*Saccharomycetes.*	

CLASS II.

Sexual reproduction by copulation.

Diatomeæ.		
Conjugateæ.	*Zygomycetes.*	

CLASS III.

Producing oospores after fertilization.

Palmellaceæ.	*Peronosporeæ.*	
Siphoneæ.	*Saprolegniaceæ.*	
Confervæ.		
Fucaceæ.		
Coleochæteæ.		
Characeæ.		

CLASS IV.

Producing a complex fruit-body [sporocarp] after fertilization.

Florideæ.	*Ascomycetes.*	
	Basidiomycetes	

LITERATURE.

In the study of the fungi the following works will be found of great service :

A. De Bary: "Morphology and Biology of the Fungi, Mycetozoa, and Bacteria."

P. A. Saccardo: "Sylloge Fungorum omnium hicusque cognitorum."

George Winter: "Die Pilze Deutschlands, Oesterreichs, und der Schweiz."

CHAPTER XVIII.

BRYOPHYTA.

434.—This division includes plants of a much greater degree of complexity than any of the preceding. In all there is a well-marked alternation of sexual and asexual generations. The first generation—that is, the one proceeding from the spore—bears the sexual organs, and hence it is called the sexual generation. After fertilization, and as a result of it, there grows a sporocarp, which consists of a case or body, in which spores arise asexually; hence this is called the asexual generation. From these spores the sexual generation is again produced.

435.—The production of the sexual generation may take place either directly or indirectly. In the first a thallus-like structure is produced directly from the germination of the spore, as in some of the Liverworts (*Anthoceros, Frullania,* etc.); in most Mosses, however, there is first produced from the spore a Conferva-like mass of threads, the pro-embryo or protonema, and upon this buds arise, which grow into the leafy sexual generation.

436.—The sexual organs of Bryophytes consist of archegonia and antheridia. The former are flask-shaped bodies, whose walls are composed of a single layer of cells. In the bottom of the cavity of each archegonium is a naked mass of protoplasm, the germ-cell, which is the essential part of the female organ. The antheridia are of various shapes; but they are generally club-shaped, or somewhat spherical, stalked bodies, whose walls, like those of the archegonia, are composed of a single layer of cells. The antheridia are filled with, usually, a great number of sperm-cells, each of which contains a single spirally coiled spermatozoid.

437.—Fertilization takes place by the spermatozoids finding their way down the neck of the archegonium (open at this time) and uniting their substance with that of the germ-cell. The first result of fertilization is the formation of a wall upon the germ-cell, which then begins to divide into a mass of cells by the formation of diagonal partitions.

438.—The sexual organs are generally numerous, and they are frequently produced in little clusters of several together, surrounded by enveloping leaves (the *perichætium*), thus forming a sort of flower. In some species the antheridia and archegonia are in the same flowers (*hermaphrodite*), while in others they are upon different parts of the same plant (*monœcious*), or upon entirely different plants (*diœcious*).

439.—The second, or asexual, generation is always developed from the fertilized germ-cell belonging to the first; but while it is nourished by the latter, there is no organic connection between the sexual and the asexual generations. The asexual generation consists of a spore-case, or *sporogonium*, with a greater or less developed stalk, or *seta*, supporting the former. The spore-case varies much in form and degree of complexity, being in some cases but a globular body filled with spores, while in others its structure is quite complex, and difficult to understand.

440.—The spores are produced from mother-cells, each of which gives rise by internal cell-division to four daughter-cells, the spores. The mature spores are provided with a double wall, the outer (*exospore*) being usually hard and somewhat roughened, while the inner (*endospore*) is thin and elastic. The interior of the spore is composed of colorless protoplasm, chlorophyll granules, starch, and minute drops of oil. In germination the endospore breaks through the exospore, and becomes prolonged as a narrow tube, which by division gives rise to the sexual stage of the plant.

441.—In a portion of the Division the plant-body is either a true thallus, or a structure which is best described as thalloid in form; in all of the Mosses, however, and some of the Liverworts, there is a differentiation into stem and leaf.

442.—No true roots are found in the Bryophyta, but in place of them there are root-hairs, consisting of single cells.

or rows of cells; these are attached to the under surface of the thallus, or to the side of the stem, and serve to support and fix the plant, as well as to absorb nutritious substances for its sustenance.

443.—The tissues of Bryophyta are much more highly developed than in the preceding divisions; the epidermis is in many cases quite well defined, and here for the first time true stomata make their appearance (paragraph 119, page 91). The greater part of the plant-body is in most cases composed of a well-developed parenchyma, composed of thin-walled cells, which are compacted into a true tissue. There is, moreover, a slight indication of the development of a fibro-vascular system in the elongated bundles of cells which occur in the leaf veins and the axial portions of the stems of some of the species. The cells immediately beneath the epidermis are much thickened in some cases, so as to form a strengthening tissue. This may be regarded as a simple kind of sclerenchyma.

444.—The Bryophytes are usually divided into two classes, the Liverworts (*Hepaticæ*) and the Mosses (*Musci*).

§ I. Class Hepaticæ.

445.—In this class of plants, commonly called the Liverworts, the plant-body is for the most part either a true thallus or a thalloid structure. Even when there is a differentiation into stem and leaves, it still retains some of the peculiarities of the thallus; thus in most cases the plant-body has two distinct and well-marked surfaces, an upper or dorsal, and an under or ventral one, the latter bearing, for the most part, the rhizoids, by means of which the plant is fixed to the ground. Growth is always from an apical cell.

446.—The tissues of the Liverworts are quite simple, and even in the leaf-bearing kinds there is but little differentiation; the leaves, when present, have no midrib or other veins, but consist of a simple plate of cells. The mode of branching is dichotomous in the lower species—*i.e.*, those with a thallus or thalloid plant-body—while in those which have stem and leaves it is lateral and monopodial.

447.—The leaves, when present, are usually in two rows (distichous), and are either opposite or alternate; they are entire, serrate, or even lobed. There is frequently a third row of leaves (called *amphigastria*) on the under side of the stem.

448.—Most Liverworts are small in size, ranging from a few millimetres to several centimetres in length. They grow for the most part in moist places, upon the ground, or upon rocks, or the bark of trees. All are chlorophyll-bearing plants, and they are usually of a green or brownish green color.

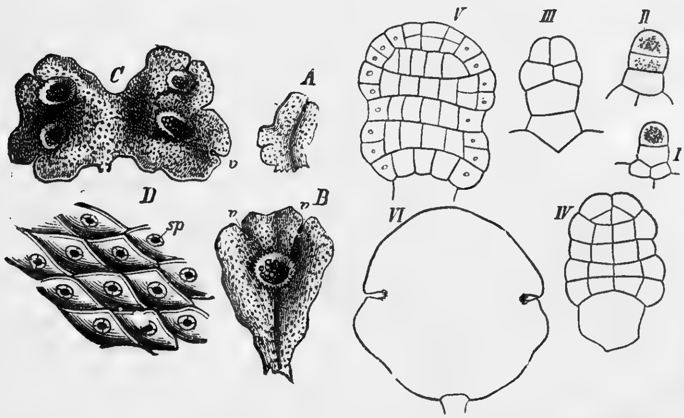


Fig. 230.—*Marchantia polymorpha.* *A*, young thallus. *B*, an older thallus, with one gemma-cup; *v*, *v*, emarginate apical region of the two young branches of the thallus. *C*, a two-lobed thallus, bearing gemma-cups. *D*, a portion of the upper surface of a thallus (magnified), showing the lozenge-shaped areolæ, each with a central stoma, *sp.* *I.* to *VI.*, development of the gemmæ. *I.*, very young; *II.*, the terminal cell divided transversely; *III.*, a later stage, with divisions in various directions; *IV.*, *V.*, still later stages; *VI.*, outline of a fully developed gemma; when it grows the new shoots will start out right and left from the two depressions on its sides.—After Sachs.

449. — The asexual reproduction of Liverworts takes place by means of bodies of a peculiar kind, called gemmæ, which are usually produced in special organs. This mode of reproduction is well illustrated in the genus *Marchantia*, in which small cup-shaped organs (4 to 6 mm. in diameter) develop upon the upper side of the thallus (*B* and *C*, Fig. 230). In each of these several hair-like papillæ grow up,

and by the repeated division of their apical cells produce upon each a little flattened mass of cells, the gemma. These

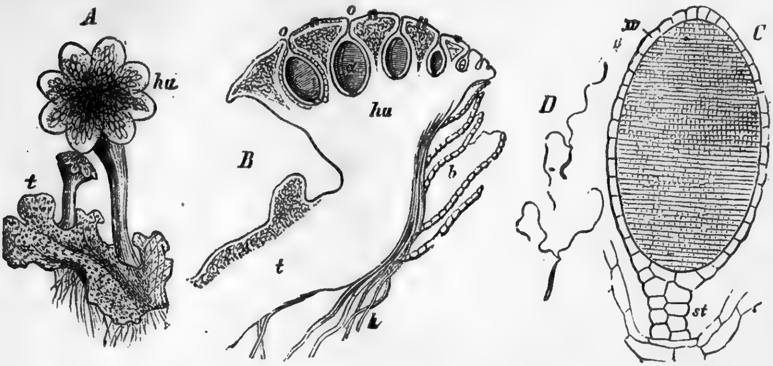


Fig. 231.—Male organs of *Marchantia polymorpha*. *A*, a portion of the thallus, *t*, with two ascending branches bearing the antheridial receptacles, *hu*. *B*, vertical section through young antheridial receptacle, *hu*; *a*, antheridium enclosed in a cavity which has a narrow opening, *o*; *t*, portion of thallus; *h*, root-hairs; *b*, leaf-like bodies seen in section. *C*, a nearly ripe antheridium; *st*, its pedicel; *w*, the wall. *D*, two spermatozoids. Variously magnified. *D* × 800.—After Sachs.

gemmæ, when full-grown, fall to the ground, and grow directly into new plants. In some cases the gemmæ are much

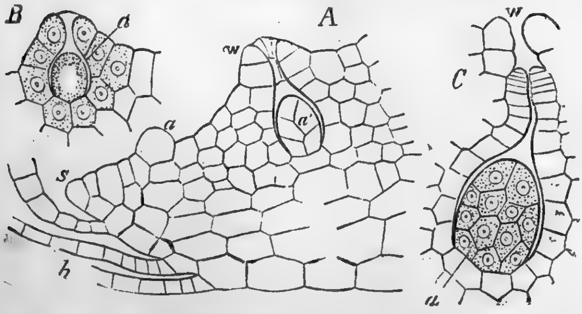


Fig. 232.—Development of the antheridia of *Riccia glauca*. *A*, longitudinal section through the apex of the thallus: *s*, apical cell of the thallus; *b*, scale-like leaves, in section; *a*, a very young antheridium; *a'*, an older antheridium, surrounded by a growth of thallus tissue, *w*. *B*, a young antheridium, *a*, overarched by a growth of the thallus. *C*, an older antheridium, in longitudinal section. × 500.—After Hofmeister.

simpler than those just described; in the Jungermanniaceæ, for example, they consist of a few cells which are spontaneously detached from the tissues in the margins of the leaves.

450.—The sexual organs are situated in depressions in the upper side of the thallus, or upon the sides or ends of the stems, and are surrounded by peculiarly developed leaves (*perichætium*) in the leaf-bearing forms.

451.—The antheridium is a more or less globular—usually stalked—body, which arises from a single cell (hence morphologically a trichome) by the repeated subdivision of its terminal cells. Its outer wall consists of a single layer of cells (*C*, Fig. 231, *w*), and its cavity is filled with a large number of sperm-cells, each of which contains a single spermatozoid. The sperm-cells escape by the breaking of the antheridium wall, and in the water in which this always takes place they rupture, and the spermatozoids are set free. Each spermatozoid is a spirally curved slender thread of

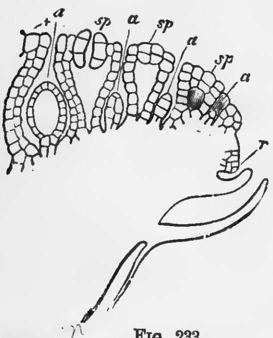


FIG. 233.

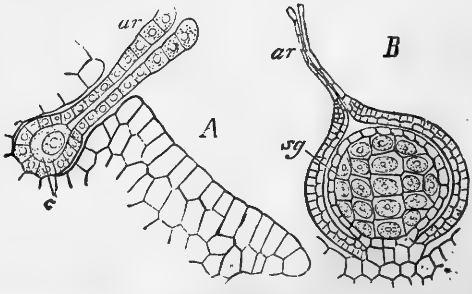


FIG. 234.

Fig. 233.—Development of the antheridia of *Marchantia polymorpha*, in a section of a young antheridial disc. *r*, the growing anterior margin of the disc; from *r* to the left are shown the antheridia (*a*, *a*, *a*, *a*) in four stages of development; at *sp*, *sp*, *sp*, are shown the stages of development of the stomata above the air cavities between the antheridia. × 300.—After Hofmeister.

Fig. 234.—*A*, longitudinal section of the apex of the thallus of *Riccia glauca*. *ar*, archegonium; *c*, germ-cell. *B*, the unripe sporogonium, *sg*, surrounded by the calyptra, which still bears the neck of the archegonium, *ar*. *A* × 560; *B* × 300.—After Hofmeister.

protoplasm, provided at the anterior end with two long cilia (*D*, Fig. 231).

452.—In some cases the antheridia are developed singly upon the upper surface of the thallus, as in *Riccia* (Fig. 232). In this particular case the antheridium is developed directly from an epidermal cell (*A*, Fig. 232, *a*), and so is at first external; it, however, soon becomes overarched

by the rapid growth of the surrounding tissue of the thallus (*A*, *B*, and *C*, Fig. 232). In other cases the antheridia are developed in great numbers upon special branches, as in *Marchantia*, which has a large "antheridial disc" (*A* and *B*, Fig. 231, *hu*), in whose upper surface are to be found many imbedded antheridia. That the antheridia are actually external in this case also, becoming apparently internal by the growing up of the surrounding tissues, is well shown in Fig. 233. In still other cases (*e.g.*, in *Jungermanniaceæ*) the antheridia are in the axils of the leaves, and occur singly or in groups.

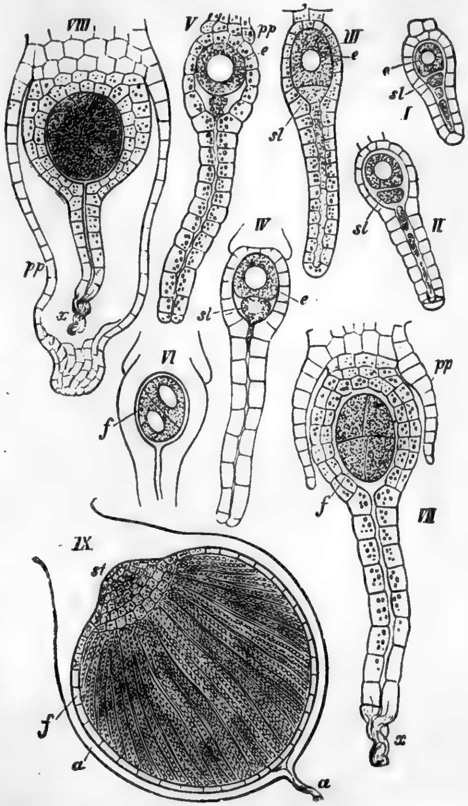


Fig. 235.—The archegonia, and origin of the sporogonium of *Marchantia polymorpha*. *I.* and *II.*, young archegonia; *e*, germ cell; *sl*, lowest cell of axial row of cells. *III.* and *IV.*, the same after the formation of a central canal by the absorption of the axial row of cells in the neck. *V.*, the same when mature and ready for fertilization. *VI.*, the base of a fertilized archegonium, the germ-cell, *f*, divided into two cells by a diagonal partition. *VII.*, later stage of the same, showing further division of the germ-cell, *f*, and the beginning of the growth of a perianth, *pp*. *VIII.*, still later stage of the same, the perianth, *pp*, now enclosing the archegonium; *x*, the withered neck of the archegonium. *IX.*, the unripe sporogonium, enclosed in the old walls of the archegonium, now called the calyptra, *a*; *f*, wall of sporogonium; *st*, the short, undeveloped stalk of the sporogonium. Inside of the sporogonium are the young elaters arranged radially, and between them are the spores. *I.* to *VIII.* × 300; *IX.* about 30.—After Sachs.

453.—The archegonium first appears as a simple papilla, composed of a single cell, which, by subdivision in various directions, gives rise to a more or less

flask-shaped body; this in its first state is composed of a layer of cells surrounding and enclosing an axial row of cells, but by the change of most of the latter into mucilage, and their consequent solution, the structure becomes tubular above. The lower cell of the axial row is the germ-cell (*A*, Fig. 234; *c*, and *e*, *e*, *e*, Fig. 235); it is a rounded naked mass of granular protoplasm. In *Anthoceros* the archegonium is very simple; a row of cells perpendicular to the surface of the thallus becomes filled with protoplasm; the lower develops into a germ-cell, and the others dissolve, forming thus a tubular opening to the germ-cell.

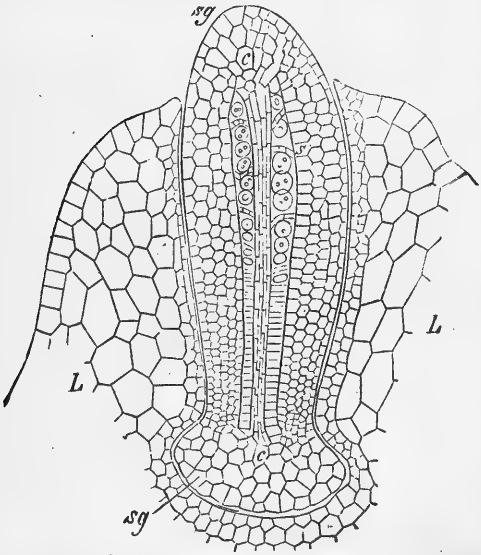


Fig. 236.—*Anthoceros lævis.* *sg*, the young sporogonium cut vertically; *L*, the involucre, which is a portion of the thallus developed so as to form a kind of sheath; *c*, *c*, the columella; *s*, the spores. × 150.—After Hofmeister.

454. — After fertilization the germ-cell divides successively in several directions, giving rise to a tissue, which undergoes different modifications in the different orders, but which becomes in every case a sporogonium (called in descriptive works a capsule) of some kind. In *Riccia* it is a simple globular case filled with spores (*B*, Fig. 234, *sg*); in *Anthoceros* it is an elongated body, with a single circular layer of spores (Fig. 236), while in other cases its structure is quite complex. In *Marchantia*, the sporogonium, when mature, is a short-stalked, rounded body, filled with spores and radially placed thin-walled cells, the elaters, each of which contains one or more spiral fibres (*IX.*, Fig. 235, and Fig. 240); it is

here surrounded by a perianth, a loose bag-like sheath, which grows up from below the base of the young sporogonium, at length completely enclosing it (*VII.* and *VIII.*, Fig. 235, *pp*).

455.—The archegonia of the Liverworts occur singly, as in *Riccia*, *Anthoceros*, etc., or grouped together, as in *Marchantia*, *Jungermannia*, and their allies. In *Marchantia* they grow in several clusters of four to six upon the under surface of the spreading top (the fertile receptacle) of a special branch of the thallus (Fig. 237). In many cases the

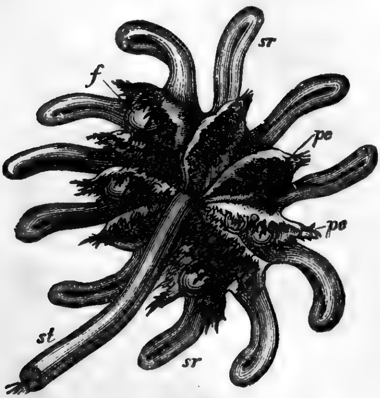


Fig. 237.

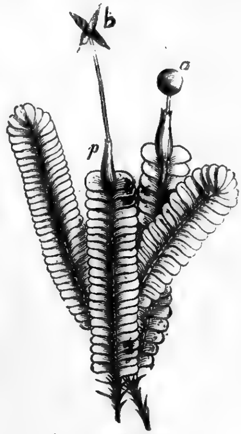


Fig. 238.

Fig. 237.—Fertile receptacle of *Marchantia polymorpha*, seen from below. *st*, its stalk, curiously grooved; *sr*, one of the rays of the star-shaped receptacle; *f*, one of the sporogonia; *pc*, *pc*, perichætia, which surround several sporogonia. × 6.—After Sachs.

Fig. 238.—Plant of *Plagiochila asplenioides*, with the bilateral leafy axis below. *p*, the perianth through whose top the sporogonium or capsule has pushed; *a*, an unripe sporogonium; *b*, a ripe sporogonium split open to permit the escape of the spores. —After Prantl.

sporogonium is, even when fully mature, sessile, or nearly so, there being but a very short stalk developed; but in the *Jungermanniaceæ*, when the sporogonium is ripening, the tissue at its base increases rapidly, and gives rise to a long slender stalk, which pushes the spore-case through the dried-up wall of the old archegonium, and raises it to the height often of several centimetres (Fig. 238).

456.—There are various ways in which the spores are set free from the ripe sporogonium or capsule. In *Riccia* it

takes place simply by the decay of the sporogonium; in *Anthoceros* the long sporogonium splits vertically into two long valves (Fig. 239), while in the greater part of the class it splits regularly into a definite number (four to six) of recurving segments; in the latter the elaters, which are present, doubtless aid in setting the spores free. The structure and development of the elaters are shown in Fig. 240.

Fig. 239.—Plant of *Anthoceros lævis*. *K*, on the right, sporogonia unopened; *K*, on the left, sporogonia opened.—After Prantl.

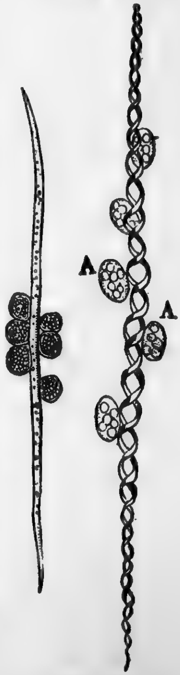


Fig. 240.—Two elaters in different stages of development. The one on the left is seen to be an elongated cell with no trace as yet of the spiral thickening of its wall. By its side are several young spores. The elater on the right is mature. It is composed of the spirally thickened portions of the wall, the intervening portions having broken away. *A*, *A*, are mature spores magnified.—From Le Maout and Decaisne.

The following are the principal orders of the Hepaticæ:

Order Ricciaceæ.—Consisting of terrestrial or aquatic annual plants of small size; the plant-body is a dichotomously branched thalloid stem, which bears a row of scale-like leaves upon the under side. The sexual organs occur singly on the upper side of the stem, and the sessile, spherical sporogonia (capsules) are immersed in it or sessile upon it; the capsule breaks irregularly upon the decay of its walls; and there are neither perianth nor elaters.

Order Anthoceroteæ. — Terrestrial annual plants with an irregularly branched thallus. The sexual organs are imbedded in the upper surface of the frond, and are of very simple structure; the sporogonia are long and narrow, and dehisce by splitting into two valves; perianth none; and the elaters, when present, imperfect and rudimentary.

Order Marchantiaceæ. — Terrestrial perennial plants, with a thick, creeping, and dichotomously branched stem, furnished beneath with numerous scale-like leaves and root-hairs; above, the stem is provided with a well-developed epidermis, and peculiar stomata of a complex structure, communicating with lozenge-shaped cavities (Figs. 78 and 79, pp. 91–2). The sexual organs are developed on special erect branches, and they may occur on the same, or on distinct plants; the sterile or antheridial branches, which

are sometimes very short, bear flattened discs in which the antheridia are immersed; the fertile or archegonial branches bear spreading discs, upon the under side of which the dependent archegonia are clustered. The ripe sporogonium (capsule) is enclosed in a perianth; it opens by splitting part way down from the top into several segments, and contains two-fibred elaters mixed with the spores.

Marchantia polymorpha, a common species, is used by quacks as a medicine.

Marchantia occurs in the Tertiary (Eocene) of Europe, but has not been detected in North America.

Order Jungermanniaceæ.—Plants composed of a thallus, a thalloid stem, or a stem with two or three rows of leaves; when there are three rows the third row is on the under side (constituting the *amphigastria*). The sexual organs are distributed monœciously or diœciously; in the thalloid species they occur much as in the *Marchantiaceæ;* in the foliose forms the antheridia "are usually in the axils of the leaves, either singly or in groups," and the archegonia are most frequently clustered upon the summits of the shoots, and are generally concealed by the leaves. The ripe sporogonium (capsule), which is usually long stalked, opens by splitting into four parts from the apex to the base; it contains one- or two-fibred elaters mixed with the spores. Many species are common on rocks and the bark of trees.

The modern genera *Jungermannia, Frullania,* and *Lejeunia* were represented in the Tertiary (Miocene).

§ II. Class Musci.

457.—The adult plant-body in this class, which includes, besides the Sphagnums, all the true Mosses, is always a leafy stem, which is rarely bilateral. It is fixed to the soil or other substratum by means of articulated root-hairs, or rhizoids, which grow out from the sides of the stem. The leaves are sessile, usually composed of a single layer of cells, and either nerveless, or traversed longitudinally by a single rib, rarely by two; they are arranged in two or three straight or spiral rows, and are usually inserted more or less obliquely to the stem.

458.—The tissues of the Mosses present a considerable advance upon those of the Liverworts. In the stem there is usually a considerable thickening of the outer layer, or layers, of cells, constituting a kind of imperfect sclerenchyma. In some cases (*Leucobryum, Barbula,* etc.) the remainder of the stem is composed of thin-walled tissue (parenchyma),

but in others (*Funaria, Mnium, Bryum,* etc.) there is an axial bundle of very narrow thin-walled-cells; in still others (*Atrichum, Polytrichum,* etc.) the cells of the central bundle are considerably thickened, and in the last-named genus there are extra-axial bundles. In a few cases there have been observed bundles of thin-walled cells extending from the leaves obliquely through the tissues of the stem to the central bundle. From the foregoing statements it cannot be doubted that the Mosses possess rudimentary fibro-vascular bundles. Stomata resembling those of the higher plants occur on the capsules; they are not found upon the leaves or stems. The stem always grows from an apical cell.

459.—Mosses are, for the most part, aerial plants, growing upon moist earth or rocks, or even upon the sides of trees, a comparatively small number of species being aquatic; they range in size from less than a millimetre to many centimetres in length, the most common height being from two to four centimetres. They are all chlorophyll-bearing plants, and are generally of a bright green color; occasionally, however, they are whitish or brownish.

460.—The sexual organs of Mosses consist of antheridia and archegonia; they are usually found upon the end of the leafy axis, and generally occur in considerable numbers. Most of the species are either monœcious or diœcious, while some are hermaphrodite. There is, however, but little value to be attached to the kind of inflorescence, as it is often different in genera which are certainly near allies. Even in the same genus some of the species may be diœcious, while others are monœcious or hermaphrodite; and occasionally, as in the genus *Bryum*, the three kinds of inflorescence are found; rarely a species is itself variable in this respect—*e.g., Bryum crudum,* which is mostly hermaphrodite, but sometimes diœcious.

461.—The antheridia are generally club-shaped, stalked bodies (spherical in *Sphagnaceæ*), with a wall composed of a single layer of cells enclosing a mass of sperm-cells, each of which contains a bi-ciliate, spirally coiled, thread-shaped spermatozoid (Fig. 242, *B*). When the antheridium is mature its wall ruptures when wet, and the sperm-cells escape in a mass

of mucilage; the walls of the sperm-cells break, and the spermatozoids are set free (Fig. 242). The antheridia are frequently intermingled with variously shaped hairs (*paraphyses*), and about the cluster there may be one or more

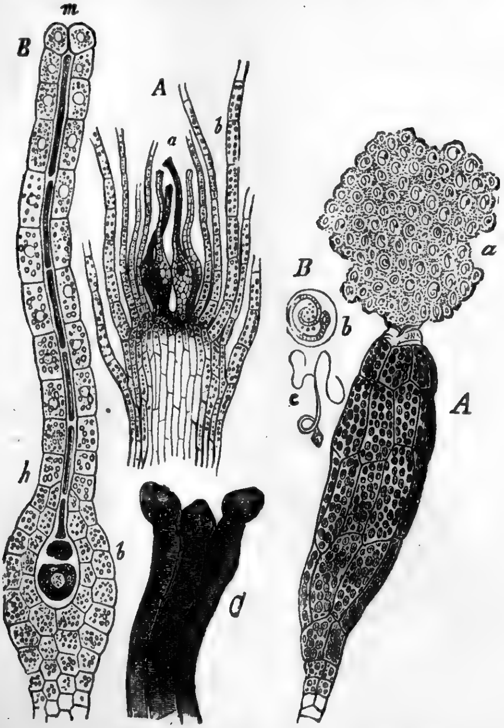


FIG. 241. FIG. 242.

Fig. 241.—Female reproductive organs of a moss, *Funaria hygrometrica*. *A*, apex of the stem; *a*, archegonia; *b*, leaves. *B*, archegonium; *b*, base; *h*, neck; *m*, mouth. *C*, mouth of fertilized archegonium. $A \times 100$, $B \times 550$.—After Sachs.

Fig. 242.—Male reproductive organs of the same moss. *A*, antheridium open and permitting the spermatozoids *a* to escape. *B*, *b*, sperm-cell of another moss (*Polytrichum*), with contained spermatozoid; *c*, spermatozoid free, with two cells at the pointed extremity. $A \times 350$, $B \times 800$.—After Sachs.

whorls of leaves or bracts, giving to the whole much of the appearance of a flower of the Phanerogams.

462.—The archegonia are elongated flask-shaped bodies, with a swelling base, and a long, slender neck (Fig. 241, *B*). The wall is composed of a single layer of cells, except

below, where there are two layers. The neck of the archegonium at first contains an axial row of cells, but these become dissolved and transformed into a mucilaginous mass just before the time of fertilization. The germ-cell lies in the lower swollen portion of the archegonium; it consists of a naked rounded mass of protoplasm. At the time of fertilization the uppermost cells of the neck of the archegonium diverge from one another, and thus form an open channel to the germ-cell.

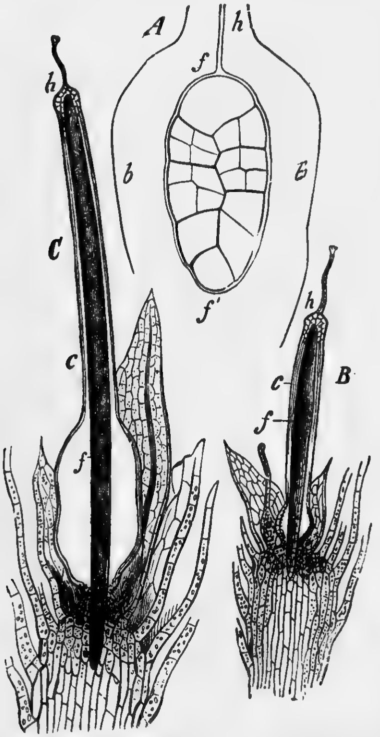


Fig. 243.—Development of the sporogonium of *Funaria hygrometrica*. *A*, longitudinal section of the archegonium, *b*, *b*, shortly after fertilization; *h*, neck; *f*, apical portion of young sporogonium; *f'*, basal portion of young sporogonium. *B*, vertical section of a female flower; *f*, young sporogonium elongating, and carrying up the remains of the old archegonium, *c* (now called the calyptra); *h*, neck of old archegonium. *C*, a later stage of the same. In *B* and *C* the sporogonia are seen to be growing downward into the tissues of the leafy stem. *A* × 500; *B* and *C* much less.—After Sachs.

463.—Fertilization takes place in the water, or in the presence of a considerable amount of moisture. The spermatozoids, which are produced in great numbers, move through the water by means of their vibratile cilia, and some of them find their way down the channels of the archegonia, where they unite their substance with the germ-cells. As a result of this union, the germ-cell surrounds itself with a wall of cellulose, and soon undergoes division in various directions, giving rise to a many-celled mass, the young sporogonium (*f*, *f'*, Fig. 243, *A*). In most Mosses the young sporogonium elongates rapidly, and while its upper end carries up the remains of

the old archegonium (*h*, Fig. 243, *B* and *C*), the lower end penetrates into the tissues of the leafy axis; the upper end develops into a spore-case, while the remainder becomes a filiform stalk (seta) of greater or less length. In the *Sphagnaceæ*, however, the sporogonium does not greatly elongate, but, on the contrary, remains quite short, while the end of the leafy axis, soon after the fertilization of the archegonium, elongates into a slender leafless stalk (*pseudopodium*), which carries up the developing sporogonium upon its upper expanded end (*v*, *ps*, Fig. 244, *B* and *C*). Essentially the same structure is found in *Andræaceæ* and *Phascaceæ*.

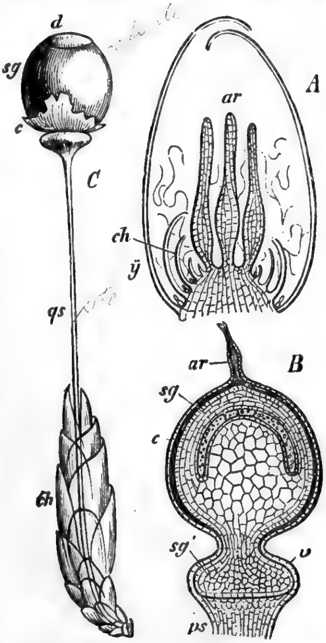


Fig. 244.—Development of the sporogonium of *Sphagnum acutifolium*. *A*, longitudinal section of a female flower; *ar*, archegonia; *ch*, young perichætial leaves; *y*, upper leaves of the shoot forming the perianth; *B*, longitudinal section of a young sporogonium, *sg*; *sg'*, foot of sporogonium, enclosed in the vaginula, *v*; *c*, calyptra; *ar*, remains of old archegonium; *ps*, the pseudopodium or branch which supports the sporogonium. In the centre of the sporogonium is the columella and the curved row of spore mother-cells. *C*, *Sphagnum squarrosum*. *sg*, ripe sporogonium; *d*, operculum; *c*, torn calyptra; *qs*, the elongated pseudopodium; *ch*, perichætial leaves. All magnified.—After Schimper.

464.—The ripe sporogonium (capsule, theca, or spore-case) is of various shapes, but generally more or less cylindrical or globose; it differs much in its particular structure in the different orders, but in all certain internal cells become spore mother-cells, which divide into four daughter-cells, the spores. The capsule, when ripe, opens by the falling off of a terminal lid (*operculum*) (*Sphagnaceæ* and *Bryaceæ*), or in a few cases by splitting vertically (*Andræaceæ*); in the small order *Phascaceæ* the capsule is indehiscent, and the spores are set free only by its decay or irregular rupture. The ripe spores are roundish or more or less angled, and have a roughened or granulated

exospore, which is generally yellow in color. Internally the spores contain, in addition to the protoplasm, oil-drops and chlorophyll granules.

465.—In the germination of the spores, the exospore is ruptured, and the endospore protrudes as a tubular filament, which elongates by the continued growth of an apical cell; partitions form at close intervals, and the threads branch freely, giving rise to a green Conferva-like mass, the *protonema* (Fig. 245, *B*). In the *Sphagnaceæ*, however, the protonema is a flattened mass, somewhat like the plant-body

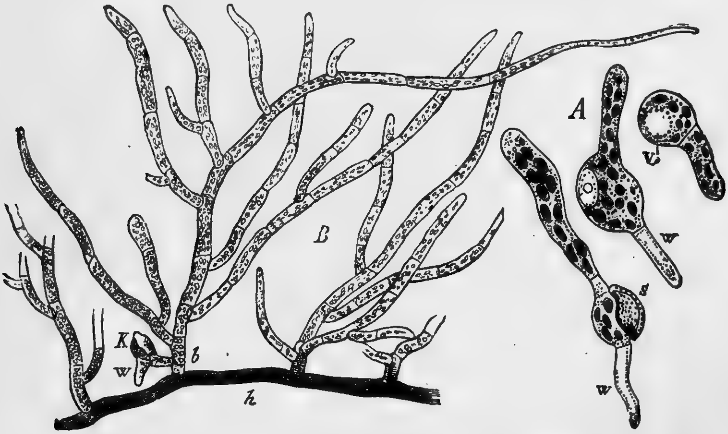


Fig. 245.—Development of *Funaria hygrometrica*. *A*, germinating spores; *s*, ruptured exospore; *w*, *w*, young root hairs—on the opposite side of the spore is the beginning of the protonema; *v*, vacuole in a germinating spore. *B*, part of a protonema three weeks after germination; *h*, a primary shoot with brown walls—from it arise several lateral branches *b*. *K*, a young bud or rudiment of a leaf-bearing axis; *w*, a small root hair. *A* × 550; *B* × 70.—After Sachs.

of the lower Liverworts. After a greater or less period of vegetation, there arise upon the protonema small buds, which develop into leaf-bearing axes (Fig. 245, *B*, *K*). These buds originate from single cells, which repeatedly divide themselves by diagonal partitions; the apical cell thus formed in each case becomes the apical cell of the bud, and the new axis. The leafy axes thus formed sooner or later bear the sexual organs, thus completing the round of life.

466.—Mosses reproduce themselves asexually, sometimes in a manner quite similar to that of the Liverworts—*e.g.*, in

Tetraphis pellucida, where the leafy axis frequently bears a terminal cup-shaped receptacle, containing many lentiform stalked gemmæ; these separate spontaneously, and give rise to a kind of protonema, and upon this buds afterward arise, from which leafy axes are developed. Many Mosses reproduce themselves by the formation of a protonema from the leaves and the root-hairs, and from buds formed upon such a protonema new plants may arise. Even the protonema is capable of an asexual reproduction of itself; sometimes its individual cells become rounded, spontaneously separate themselves, become thicker walled, and then remain inactive for a time; they thus remind one of the conidia of some Thallophytes.

There are four well-marked orders of Mosses, as follows:

Order Sphagnaceæ.—The plants of this order are large, soft, and usually pale colored; they inhabit bogs and swampy places, and are known as the Peat Mosses. The protonema is a flat thallus, or composed of branched filaments, accordingly as it has developed upon a solid substratum or in water; the leafy axis is usually much elongated, and as it dies away below it grows at the summit; the leaves are usually five-ranked, and are composed of two kinds of tissue, viz., (1) one made up of small chlorophyll-bearing cells, and (2) one made up of large perforated cells; the latter are usually filled with water, and to them is due the well-known power possessed by the Peat Mosses, of retaining moisture for a great length of time. Root-hairs (rhizoids) are present only in young plants, their place being taken by the reflexed branches, which are always abundant.

The inflorescence is monœcious or diœcious; the rounded (almost spherical) antheridia occur singly by the sides of the leaves of catkin-like branches (not axillary, as stated in some books); the archegonia are developed upon the ends of certain branches (*A*, Fig. 244). The ripe sporogonium (capsule or spore-case) is globose, or nearly so; its seta is short, but it is borne upon a more or less elongated pseudopodium, which resembles a seta. The old archegonium (calyptra) is ruptured irregularly by the growing sporogonium, and forms only a very imperfect cap to the spore-case. In the development of the spores the cells of a layer parallel to the surface of the upper half of the capsule become modified as spore mother-cells (*B*, Fig. 244). At maturity a circular portion of the apex of the capsule spontaneously separates as a lid (*operculum*), and allows the spores to escape (*C*, Fig. 244, *d*).

The order contains but a single genus, *Sphagnum*, represented in the United States by twenty-seven species. These are of some economic account, as they furnish a most excellent material for "packing" in the transportation of living plants.

The genus *Sphagnum* was represented in the Tertiary (Miocene) of Europe.

Order Andræaceæ.—In this small order the little plants of which it is composed have a short-stalked sporogonium, raised upon a pseudopodium, as in the *Sphagnaceæ;* the sporogonium contains a layer of spore-forming tissue, disposed as in the preceding order; but the ripe capsule opens by splitting into four longitudinal valves, in this reminding one of the *Jungermanniaceæ.* In the growth of the sporogonium the old archegonium is torn away at its base, and carried up as a cap (calyptra), which covers the apex of the capsule.

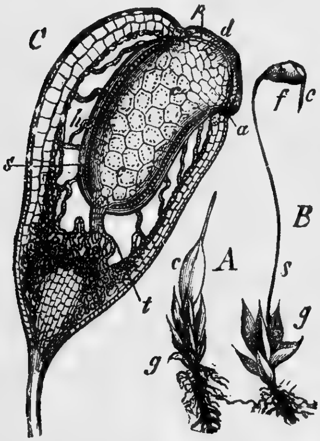


Fig. 246.—*Funaria hygrometrica.* *A*, a young leafy plant, *g*, with sporogonium still covered with the calyptra, *c*. *B*, leafy plant, *g*, with nearly ripe sporogonium, *f*; *c*, the calyptra; *s*, seta. *C*, longitudinal section of a capsule; *c*, *c*, columella; *d*, operculum or lid, which will separate from the remainder of the capsule at *a*; *p*, peristome; *s*, spore-bearing layer; *h*, air cavity surrounding the columella, and crossed by confervoid filaments; *t*, inferior connection of the columella with the tissues of the capsule. *A* and *B* slightly magnified; *C* about 40 diameters.—After Sachs.

The principal genus is *Andræa*, represented in the United States by a few alpine or sub-alpine species of brownish or blackish rock-loving Mosses.

Order Phascaceæ.—These small Mosses are peculiar in having but a little development of leafy axis, and in their persistent protonema. The sporogonium is short-stalked, or sessile, and the pseudopodium is very short, or entirely wanting. The spores are, in the simplest genus (*Archidium*), developed from a single mother-cell, while in the higher ones they develop from a layer of mother-cells, much as in the next order. The capsule is indehiscent, and the spores are set free only by its decay. The old archegonium persists as a calyptra covering the capsule.

The principal genera are *Archidium*, *Phascum*, and *Bruchia.* The species are terrestrial, and many are annuals.

In the Tertiary (Miocene) of Europe a fossil species of *Phascum* has been found.

Order Bryaceæ. — The plants of this order constitute the true Mosses. They are usually bright green (in a few genera brownish), and in the great majority of instances live upon moist ground and rocks, or upon the bark of trees; in a comparatively small number of cases the species live in the water.

In the development of their tissues and the complex structure of their sporogonia the Bryaceæ clearly stand at the head of the Bryophyte Division. The tissues, as indicated above (paragraph 458), attain

in some cases a development which foreshadows the differentiation of the stem into the epidermal, fibro-vascular, and fundamental systems of the higher plants. In *Polytrichum*, for example, there can be no doubt that the axial and extra-axial bundles of elongated cells with thickened walls found in the stem represent the fibro-vascular bundles of the Pteridophytes and Phanerogams; the bundles of elongated thin-walled cells which pass downward through the stem from the base of the leaf, in *Splachnum*, must also be regarded as representing rudimentary foliar bundles.

Fig. 247.—Two capsules of *Bryum argenteum*. The one on the left is still perfect; at its apex is shown the lid or operculum; the one on the right has dropped its operculum, exposing the peristome of long fringe-like teeth. Magnified.

While these higher Mosses cannot properly be classed with vascular plants, their tissues in some cases reach so high a development as to show that there is no abrupt change in passing from the so-called non-vascular plants to the vascular ones.

The inflorescence of Bryaceæ is hermaphrodite, monœcious, or diœcious. The sexual organs are situated on the apex of the main stem (Acrocarpæ), or of short lateral branches (Pleurocarpæ). The sporogonium, in its development, carries up the old archegonium as a calyptra, which quickly falls away in some genera (*e.g.*, *Bryum*, *Bartramia*, etc.), while in others (*e.g.*, *Polytrichum*, *Pogonatum*, etc.) it persists as a closely fitting covering of the capsule; between these two extremes there are all gradations.

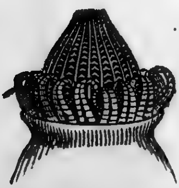


Fig. 248.—Apical part of the capsule of *Fontinalis antipyretica*, showing the double peristome. The outer row is made up of *teeth*, the inner of *cilia*. Magnified.

The sporogonium is usually long stalked (Fig. 246, *B*). The capsule is generally more or less ovoid or cylindrical. It is at first composed of parenchymatous tissue, which entirely fills up its interior; as it enlarges, however, an annular intercellular air cavity forms, separating a cylindrical axial portion from the outer portion, which forms the wall of the capsule. The axial cylinder remains in connection with the remainder of the capsule at its top and bottom (*t*, Fig. 246, *C*), and it is, moreover, slightly connected with the capsule walls by chlorophyll-bearing confervoid filaments, which pass across the air cavity. The rather dense tissues below and surrounding the air cavity in the immature capsule are composed of chlorophyll-bearing cells, and the epidermis covering these portions is supplied with stomata. The spores are developed from a layer of cells (the third or fourth from the outside) in the axial cylinder (*s*, Fig. 246, *C*); and each cell of the spore-bearing layer produces four spores. The portion of the axial cylinder within the spore-bearing

layer is called the columella (c, c', Fig. 246, C), while the two or three layers of cells exterior to it constitute the spore-sac.

In all the members of this order, the capsule, when ripe, opens by the falling away of a lid (*operculum*), which is composed for the most part of the epidermis covering the apical portion (Fig. 247). In most of the genera, when the operculum falls off, one or two rows of teeth (the peristome) are exposed, surrounding the opening of the capsule (Fig. 248). These teeth, which are always some multiple of four (4, 8, 16, 32, or 64), are in most cases formed respectively of the thickened outer and inner walls of rows of cells which lie beneath and parallel to the wall of the operculum, and converge toward its centre. Each tooth is thus made up of parts of several cells, and the transverse lines seen upon it are the thickened transverse walls which formerly separated the original cell cavities.

The peristome of *Polytrichum* and its allies is composed of bundles of thickened cells, hence they are much firmer than in those genera in which they are made of fragments of cell membranes.

The Bryaceæ include many genera, which are widely distributed throughout the world. The genera arrange themselves under two groups (sub-orders), according as the sporogonia are terminal or lateral, with reference to the main axis; the first constitute the *Acrocarpæ*, including *Funaria, Bryum, Mnium, Polytrichum*, etc.; those with lateral sporogonia constitute the *Pleurocarpæ*, and include *Fontinalis, Climacium, Hypnum*, etc.

In the Tertiary of Europe the order is represented by an Eocene species of *Muscites*, and Miocene species of the modern genera *Fontinalis, Dicranum, Barbula, Polytrichum, Hypnum*, etc. A single species of *Hypnum* from the Tertiary of Colorado is the only American fossil of this order yet detected.

The most valuable systematic works for the student of the Bryophytes of this country are "Musci and Hepaticæ of the Eastern United States," by W. S. Sullivant, 1871; "Icones Muscorum," by the same author, 1864–74; and "Catalogue of Pacific Coast Mosses," by L. Lesquereux, 1868; "Manual of the Mosses of North America," by Leo Lesquereux and Thomas P. James, 1884; "Descriptive Catalogue of the North American Hepaticæ North of Mexico," by L. M. Underwood, 1884.

CHAPTER XIX.

PTERIDOPHYTA.

467.—The plants of this Division constitute the so-called Vascular Cryptogams. They present an alternation of sexual and asexual generations, much as in the Bryophytes, but in the higher orders it shows signs of disappearing. The first generation proceeds directly from the germination of the spore; it is made up of simple tissues, and is usually short-lived; it bears the sexual organs, and hence is called the sexual generation. The second generation, which results from the fertilization of a germ-cell developed upon the preceding one, is long-lived, and made up in most cases of tissues of a high order, and the plant-body is differentiated into root, stem, and leaves; upon this second generation spores arise asexually year after year, and from these spores the sexual generation is again produced.

468.—The sexual generation, called the Prothallium, is generally a flattened thallus-like growth, somewhat resembling the plant-body of the lower Bryophytes. It is always small, and composed throughout of parenchyma disposed in one, or at most a few layers; on its under surface it generally produces root-hairs (rhizoids), which serve to fix it to the ground, and doubtless also serve as organs of nutrition. The cells of the prothallium are in most cases richly supplied with chlorophyll, by means of which they elaborate material for its growth.

469.—When the prothallia have become sufficiently large, they develop the sexual organs, the antheridia and archegonia. These are formed in essentially the same manner as they are in the two lower orders of Hepaticæ (*Ricciaceæ* and *Anthoceroteæ*). They are more or less imbedded in the sur-

face of the prothallium, and consist of masses of cells, enclosing in each case a single cell, which develops into one germ-cell (in the archegonia), or a number of sperm-cells (in the antheridia). The sperm-cells produce spirally coiled spermatozoids, which fertilize the germ-cell by passing down the canal in the neck of each archegonium. In many of the plants of this division there is a strong tendency toward diœciousness in the prothallia, and in the higher genera it becomes the invariable rule.

470.—The result of fertilization is the formation of a young plant, by the growth and successive division of the fertilized cell. In its first stages the new plant is usually quite simple, but it soon becomes, in the greater part of the Division, a leafy plant with highly developed tissues. After a greater or less period of vegetation the new plant produces spores by the internal cell-division of certain mother-cells, each of the latter producing four spores. The particular structure of the spore-bearing organs and the place of their appearance are quite different in the different classes. In many cases they are produced upon the surface of the ordinary green leaves, in other cases upon modified leaves, while in still others upon the bases of the leaves, in their axils. The spores are in most cases of one kind, but in certain genera there are large spores (macrospores), and small ones (microspores).

471.—True roots first make their appearance in this division. A root is developed upon the young plant, but this never attains a great size, and others form in acropetal order upon the stem, and even occasionally upon the leaves.

472.—In the Pteridophytes the three tissue systems—epidermal, fibro-vascular, and fundamental—attain a good degree of development. The epidermis is distinct, and contains stomata similar in form and position to those of the Phanerogams. In many cases there is a strong development of trichomes, as in the Ferns, where the young leaves are usually densely covered with scurfy hairs. The fibro-vascular bundles are always closed, and generally are what De Bary calls concentric bundles; in the Equisetinæ, however, collateral bundles occur, and in Lycopodinæ radial bundles.

The bundles vary considerably as to the tissues they contain, but they generally possess tracheary and sieve tissues; the former is usually well-developed as spiral, scalariform, or pitted. Sieve tissue is, as a rule, not so well developed as the former, consisting for the most part of thin-walled, elongated cells, in which the characteristic sieves are less regularly formed. Fibrous tissue occurs only to a limited extent as a constituent of the fibro-vascular bundles. Parenchyma is also found in them, but, like the former, it is usually not abundant. The fundamental system of tissues includes various forms of parenchyma and sclerenchyma; the latter, however, is frequently wanting. Collenchyma and laticiferous tissue are not found in the greater part of the Division; but the former occurs in Marattiaceæ, in which order, according to Sachs' observations, there are also indications of a rudimentary laticiferous tissue.

§ I. CLASS EQUISETINÆ.

473.—In the plants of this class the plant-body (of the asexual generation) consists of a hollow elongated and jointed axis, bearing upon each node a whorl of narrow united leaves, which form a close sheath (*s*, Fig. 249); the stem is always grooved or striate, and is usually rough and hard from the large amount of silica deposited in the epidermis. The branches arise by the side of the axils of the leaves constituting the sheaths, and consequently they are in whorls. Both the main axis and the branches are in most cases richly supplied with chlorophyll-bearing parenchyma; in some of the species (*e.g.*, *Equisetum Telmateia* and *E. arvense*) the stems which bear the spores are destitute of chlorophyll. All the species develop numerous colorless branching underground stems, which bear roots and rudimentary sheaths, and which each year send up the vegetating and spore-bearing stems. Both root and stem grow from an apical cell.

474.—In common with most members of this division, the Equisetinæ are perennial plants. In some species the underground portions only persist, the aerial stems dying at the end of each year, as is the case in *E. Telmateia*, *E. arvense*,

E. sylvaticum, E. limosum, and some other species. In other species, as *E. hyemale, E. lævigatum,* the aerial stems also persist; the latter are hence known as perennial-stemmed.

475.—The prothallia are irregularly branched thallus-like growths, composed of chlorophyll-bearing parenchymatous cells arranged in one or more layers. Upon the under side they bear root-hairs, which fix them to the ground. They are usually small in size, ranging from two or three to ten or twelve mm. in length. In most species the prothallia are diœcious, bearing but one kind of sexual organ upon each, and in such cases it always happens that those which bear the antheridia are much smaller than those which bear archegonia. Both kinds live but for a short time, the whole period of their existence usually not extending beyond a few months; the male prothallia appear to endure for a somewhat shorter period than those which bear archegonia.

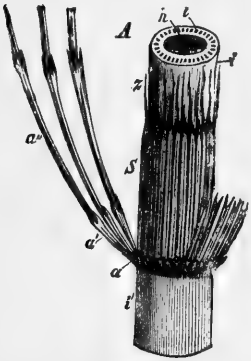


Fig. 249.—Portion of the upright stem of *Equisetum Telmateia* (nat. size). *i, i,* internodes; *h,* central hollow space of internode; *l,* air spaces (lacunæ) in the cortex; *s,* sheath of united leaves; *z,* their separate apices (teeth); *a, a', a'',* basal internodes of lateral branches.—After Sachs.

476.—The antheridia occur upon the ends or margins of the prothallia; they arise from the repeated division of a marginal cell, thus forming an inner mass of cells rich in protoplasm, and a covering layer (*an'*, Fig. 250, *A*). By the continued division of the inner cells 100 to 150 cubical cells are formed, each of which contains a single sperm-cell; somewhat later the walls of the cubical cells dissolve, and the sperm-cells become free in the antheridial cavity, from which they are soon allowed to escape by the separation of the apical cells of the enveloping layer (*an,* Fig. 250, *A*). At this time each sperm-cell contains a spermatozoid, which soon escapes by the rupture of the cell-wall. Each spermatozoid is a thick, spirally coiled filament of protoplasm, tapering anteriorly, where it is provided with numerous cilia, which give it motility.

477.—The archegonia arise upon the anterior edge of the prothallium, from the division of single cells. The mother-cell of the archegonium undergoes several divisions, resulting in the formation of a germ-cell, surrounded by one or more layers of cells. The germ-cell lies at a considerable depth beneath the general surface of the prothallium, above

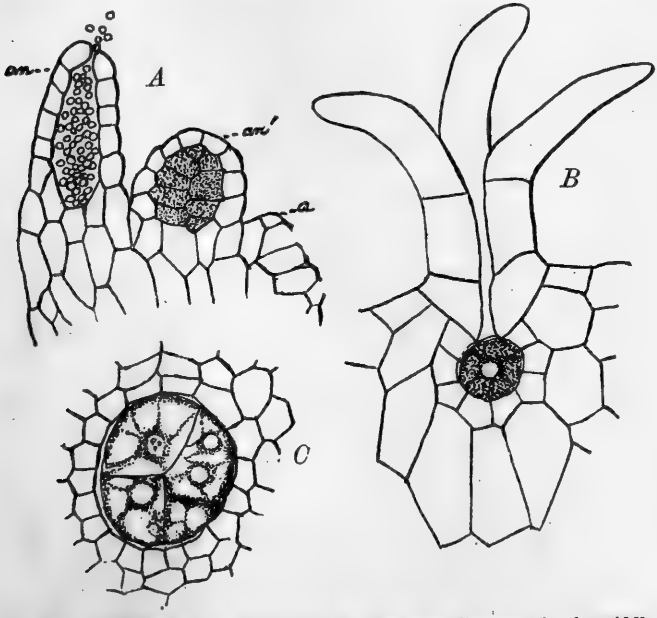


Fig. 250.—*A*, fragment of a prothallium of *Equisetum limosum* (in the middle of July); *a*, an apical cell of a growing point; *an*, a ripe antheridium, with escaping sperm-cells; *an'*, a young antheridium. *B*, longitudinal section of an archegonium of *Equisetum arvense* immediately after the opening of its apex, showing the germ-cell in the cavity below, surrounded by the parenchyma of the prothallium. *C*, longitudinal section of the germ-cell, or rudimentary embryo, of *E. arvense*, shortly after fertilization; it is seen to be already divided into four parts, and the whole is surrounded by the parenchyma of the prothallium. *A* × 200; *B* and *C* × 300.—After Hofmeister.

which the surrounding tissue of the archegonium is prolonged into a four-sided tube. At the period of maturity of the archegonium, the projecting cells diverge from each other, and form an open channel to the germ-cell (*B*, Fig. 250).

478.—After fertilization the germ-cell undergoes division

into four cells (*C*, Fig. 250), and from these the young plant of the asexual generation is developed. The young plant is quite simple, having small internodes, bearing sheaths which contain but three leaves; larger shoots soon arise, with larger internodes and sheaths having more leaves, and these are followed by others still larger, until at last the full size is reached.

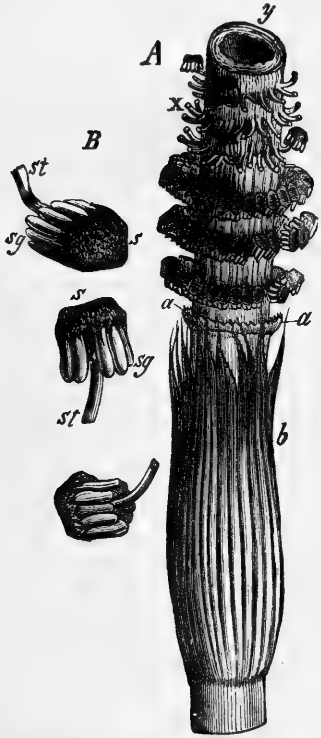


Fig. 251.—*Equisetum Telmateia.* *A*, upper part of a fertile stem, with lower half of the spike (nat. size); *b*, sheath of united leaves; *a*, annulus or ring formed of imperfectly developed leaves; *x*, the pedicels of peltate scales which have been cut off; *y*, section of the rachis of the spike. *B*, peltate scales, *s*, *s*, in various positions (slightly magnified); *sg*, the sporangia borne on the under side of the scales; *st*, *st*, the pedicels of the scales.—After Sachs.

479.—The spores of the Equisetinæ are produced either upon the ordinary green stems, as in *Equisetum limosum* and *E. hyemale*, or upon colorless or brownish stems, which develop early, and, after bearing the spores, die and disappear, as in *E. Telmateia* and *E. arvense.* The sporangia are developed upon modified leaves, upon the ends of the stems. The spore-bearing leaves, like the ordinary ones, are in whorls; each leaf is, however, peltate in form, and borne upon a short stalk (*st*, Fig. 251, *B*). These peltate leaves (usually called the peltate scales) are collected into cone-shaped clusters, and by their mutual pressure each scale becomes more or less hexagonal in outline. Upon the under surface of each scale there arise five to nine or ten cellular masses, which enlarge and become sac-shaped sporangia; certain inner cells become spore mother-cells, and from each of these four spherical spores are produced. The

sporangia, when mature, appear as nearly cylindrical sacs attached by one end to the under surfaces of the peltate scales (*sg*, Fig. 251, *B*); they open at maturity by a slit along the inner face—*i.e.*, the side next to the pedicel of the peltate scale.

480.—In their development the spores acquire three concentric coats, and as they approach maturity the outer one, which has previously become spirally thickened, splits from two opposite points into four narrow spiral filaments, which are united with one another and the spore at a common point. These filaments are hygroscopic, and they roll and unroll with the slightest changes in the moisture of the air; when moistened they wrap tightly around the spore, but when dry they unroll and become more or less reflexed. By the changes of position which they undergo, they move the spores very considerably, and are doubtless useful in emptying the sporangia after dehiscence—hence they have been called *Elaters.*

481.—The spores germinate soon after falling upon water or moist earth; they first enlarge, and then divide by a partition into two parts of unequal size, the larger of which contains chlorophyll granules, while the smaller one is colorless; the latter grows rapidly into an elongated root-hair. The larger cell divides first into two cells, and then usually one of these divides again, and so on, giving rise to a simple prothallium, composed of a single layer of cells; this enlarges and increases in size, until it reaches the stage in which it bears the sexual organs (paragraph 475).

482. Tissues.—The epidermis is remarkable for the large quantity of silica which it contains, mainly in the outer walls of the cells. The epidermal cells are mostly narrow and elongated, and are arranged in vertical rows. The stomata, which are present in all the chlorophyll-bearing parts of the plant, are arranged with more or less regularity in longitudinal rows; on the stem they occur in the channels between the numerous ridges. They resemble pretty closely the stomata of the Phanerogams in their structure. The fibro-vascular bundles of the stem are disposed in a circle, as seen in a cross-section, and they run through the funda-

mental tissues from node to node, parallel with, but independent of, one another. At the nodes they split into two branches, which unite right and left with corresponding branches of other bundles, and thus form the bundles of the next internode. The bundles of successive internodes thus alternate with one another. Each leaf of the leaf-sheaths sends down a bundle, which joins a bundle in the stem at the point where two descending branches of contiguous bundles from the upper internode unite to form a bundle in the lower internode. The bundles are thus seen to be of the "common" type—*i.e.*, they are common to both stem and leaves. As to their construction, they are collateral, and contain tracheary, sieve and fibrous tissues (paragraph 139, and Fig. 99). The remainder of the stem (the fundamental portion) is made up for the most part of parenchyma; in the cortical portion of the vegetating shoots it contains an abundance of chlorophyll, and it is here frequently penetrated by large longitudinal canals (*l*, Fig. 249); in the medullary portion a great central canal soon appears by the rapid growth causing a rupture of the tissues (*h*, Fig. 249). There are frequently found in the hypodermal portions of the fundamental systems bands of thick-walled tissue, which are either sclerenchymatous or fibrous.

(*a*) This class contains but one living order, the EQUISETACEÆ, having the characters of the class as given above. In ancient geological times the Calamites and their allies constituted a distinct order, the *Calamarieæ*, now extinct; they differed from the *Equisetaceæ* in having fibro-vascular bundles which increased exogenously. The *Calamarieæ* were represented in the Devonian by a species of *Asterophyllites*. In the Carboniferous period there were many species of the genera *Calamites*, *Calamocladus*, *Calamostachys*, *Sphenophyllum*, etc. In the Permian the order became extinct.

(*b*) The order *Equisetaceæ* includes but a single genus, *Equisetum*, which contains about twenty-five species. None of the species attain a great size, the usual height being from 20 to 100 cm. (8 to 40 inches); one species (*E. giganteum*) in tropical South America attains a height of 9 to 10 metres (30 feet or more), but it is very slender, being no more than 20 to 25 mm. (1 inch or less) in diameter. The silicious stems of *E. hyemale*, a common species, are sometimes used for scouring knives and other articles.

(*c*) The germination of the spores of Equisetinæ may be studied by

placing fresh spores in water, or upon moist earth or moist pieces of porous pottery. It must, however, be borne in mind that within a few days after reaching maturity the spores lose their power of germinating.

(*d*) The oldest genus of this order is *Equisetites*, represented in the Carboniferous by several species. *Equisetum* extends from the lower Secondary (Triassic) to the present.

§ II. Class Filicinæ.

483.—The plant-body of the asexual generation in this class consists of a solid stem, bearing roots and broadly expanded leaves, the latter usually on long petioles. The stems are mostly horizontal and underground, but in some cases they rise to a considerable height vertically in the air. The leaves arise singly upon the stems, and grow upward from the rhizome (horizontal stem), or are borne as a crown upon the more or less elongated upright stem. The leaves are in nearly all cases supplied with fibro-vascular bundles, which run as veins through the parenchyma; there is usually a prominent midrib, upon each side of which the parenchyma is permeated with small veins, which are *free* (running more or less parallel from the midrib to the margin), or *reticulated*.

484.—The Filicinæ are for the most part terrestrial plants of considerable size, a few only being small or of an aquatic habit. They are all richly supplied with chlorophyll, and none are in any degree parasitic. Nearly all the species are perennial, in some cases, however, dying down to the ground at the end of the summer, the underground portions alone surviving the winter.

485.—The prothallium in the Filicinæ is a small cellular body,* composed in most cases of chlorophyll-bearing parenchyma. It is frequently somewhat heart-shaped,

* Dr. Farlow, in a paper on "An Asexual Growth from the Prothallus of Pteris cretica," in *Proc. Am. Acad. Arts and Sciences*, 1874, and *Qr. Jour. Mic. Science*, 1874, described certain prothallia in which scalariform vessels were found by him. These abnormal prothallia produced new plants directly, without the intervention of the usual process of fertilization; the scalariform vessels of the prothallia were in every case continuous with those in the new plants.

and is generally provided with root-hairs on its under surface, by means of which it secures nourishment for its independent growth (Fig. 252). In the *Rhizocarpeæ* the prothallium is so reduced as to be only a small outgrowth of the germinating spore.

486.—Both kinds of sexual organs usually occur upon the same prothallium. The antheridia consist of a few or many sperm-cells, which may or may not be surrounded by a wall

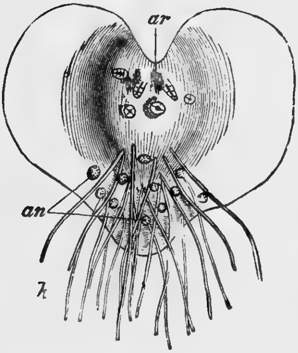


Fig. 252.

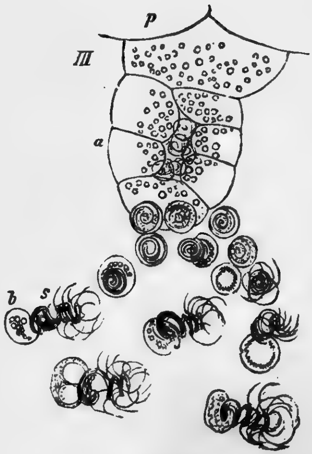


Fig. 253.

Fig. 252.—A prothallium of a fern, seen from the under side. *h*, the root-hairs growing from the basal end of the prothallium; *an*, the antheridia scattered among the root-hairs; *ar*, archegonia near the apex. × 10.—After Prantl.

Fig. 253.—Mature antheridium of *Adiantum Capillus-Veneris*. *p*, cells of prothallium; *a*, wall of antheridium—the sperm-cells are seen escaping, in each a spermatozoid is coiled up; *s*, the spermatozoids; *b*, the protoplasm of the sperm-cells still attached to the spermatozoids. × 550.—After Sachs.

of other cells. In the Ferns (*Filices*) they are few-celled bodies, which project from the basal portion of the under surface of the prothallium; one of the interior cells becomes divided into sperm-cells, in each of which is a spirally coiled spermatozoid (Fig. 253). In the other orders the antheridia are not confined to the under surface of the prothallium, and in some of the *Rhizocarpeæ* nearly the whole of the contents of a microspore is developed into one antheridium filled with sperm-cells.

487.—The archegonia of the Ferns are cellular projections from the anterior portion of the under surface of the prothallium. The germ-cell is situated at the base of an axial row of cells; the latter dissolve, and thus form a canal, which becomes open by the separation of the apical cells of the archegonium wall (Fig. 254). The archegonia of the other Filicinæ do not differ much as to structure, but like the antheridia, they are not confined to the under surface of the prothallium.

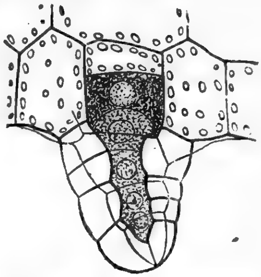


Fig. 254.—Young archegonium of *Pteris serrulata*, showing a few cells of the prothallium, containing chlorophyll, and the axial row of cells and the germ-cell, filled with dense and granulated protoplasm. Highly magnified.—After Sachs.

488. — After fertilization the germ-cell divides (in the known cases) into four parts, as in *Equisetinæ*, and by the growth and development of these the young plant of the asexual generation is produced. The young plant is at first very simple, the first leaves being much smaller and less divided than those which appear later (Figs. 255 and 256).

Fig. 255.—Prothallium and young plant of *Adiantum Capillus-Veneris*, seen from below. *p*, the prothallium; *h*, root-hairs of prothallium; *b*, first leaf of young plant; *w'*, the first root of the young plant; *w''*, the second root. × 3.—After Sachs.

489.—The spores are developed upon the leaves. They are contained in sporangia, which occur singly or in clusters upon the surface, or on the margins of the more or less modified leaves; in one order, the *Ophioglossaceæ*, the single sporangia occur in the tissues of the greatly modified leaves. The spores are all of one kind, excepting in the *Rhizocarpeæ*, in which there are two sizes, viz., microspores and macrospores. The sporangia of the true Ferns (*Filices*) have a ring of cells belonging to their walls, peculiarly thickened, forming an elastic ring, which ruptures the mature sporangium; in the other orders there is no such elastic ring, and the dehiscence is usually by the simple splitting of the dried wall.

490.—The Filicinæ may be here arranged under four orders, as follows:*

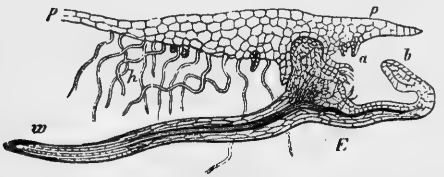


Fig. 256.—Prothallium and young plant of *Adiantum Capillus-Veneris*, seen in vertical longitudinal section. *p*, *p*, the prothallium; *a*, archegonia; *h*, root-hair; *E*, the young plant; *w*, its first root; *b*, its first leaf. × about 10.—After Sachs.

I. Isosporeæ.—Spores of one kind.

Order 1. Filices, the true Ferns. Sporangia composed of modified trichomes, each developed from a single epidermal cell, produced in clusters on the surface of ordinary or slightly modified leaves. Each sporangium with an elastic ring. No stipules.

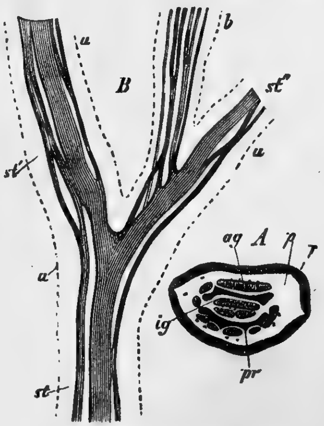


Fig. 257.—*A*, a transverse section of the stem (rhizome) of *Pteris aquilina*, slightly enlarged. *r*, brown sclerenchyma, forming a hard sheath beneath the epidermis; *p*, colorless parenchyma of the fundamental system; *ig*, inner fibro-vascular bundles; *ag*, the broad upper band of the outer bundle zone; *pr*, a band of elongated thick-walled cells, sclerenchyma or fibrous tissue—a second one occurs on the other side of the central bundles. *B*, the separated upper fibro-vascular bundle of the stem (rhizome), *st*, and its branches, *st'*, *st''*; *b*, bundles of the leaf stalk; *u*, *u*, *u*, outline of the stem.—After Sachs.

Order 2. Marattiaceæ, the Ringless Ferns. Sporangia produced from a group of epidermal cells; the ring either rudimentary or wanting. The large, much-branched leaves with stipules.

Order 3. Ophioglossaceæ, the Adder-Tongues. Sporangia formed by groups of cells in the interior of a modified branch of the sheathing leaf. The ring is absent.

II. Heterosporeæ.—Spores of two kinds.

Order 4. Rhizocarpeæ, the Pepperworts. Sporangia composed of modified trichomes (?); the microsporangia containing many microspores,

---

* This arrangement is essentially that modification of Sachs' proposed by Professor McNab. See his "Outlines of the Classification of Plants," American edition, Chapter VII.

the macrosporangia usually containing only one macrospore. Sporangia in clusters, enclosed in modified leaves or "fruits."

Order Filices, the true Ferns. The prothallia of the Ferns are green thallus-like structures, growing upon the surface of the ground,

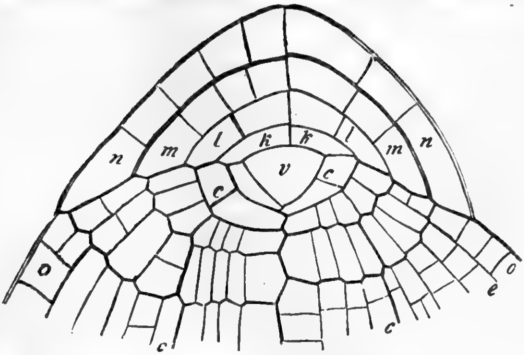


Fig. 257*a*.—Longitudinal section of the apex of the root of *Pteris hastata*. *v*, apical cell; *o*, *o*, epidermis; *e*, cortical tissue; *c–c*, *c–c*, the primary fibro-vascular bundles; *n*, *m*, *l*, *k*, the root-cap; *k*, *k*, daughter-cells recently cut off from the apical cell.—After Nägeli and Leitgeb.

and composed at first of but a single row of cells, but later of extended layers of cells. They are monœcious, and bear their antheridia on the basal portion of the under surface, while the archegonia are found near the apical margin of the same surface. After fertilization the germ-cell divides into four parts, the uppermost one (or two) of which becomes the foot, or organ which remains in contact with the prothallium; one of the other parts develops into the first root, and the other into the first leaf. The young plant is thus formed on the under side of the prothallium, from which it grows up as shown in Figs. 256 and 255.

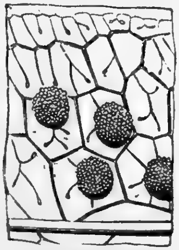


Fig. 257*b*.—Portion of under surface of a leaf of *Polypodium*, showing sori.—From Le Maout and Decaisne.

The stems of Ferns are mostly short, or slender and creeping in our species, but in the tropics they are often of considerable height and thickness, some tree-ferns attaining the height of 24 metres or more (80 feet or more). They increase in length only, and this takes place by the continued division of an apical cell. They contain flat fibro-vascular bundles (Fig. 257, *A* and *B*), which are usually disposed in a single circle, as seen in a cross-section, but in some cases there are bundles in the medullary portion also. On account of the presence of thick masses of thick-walled cells, (scleren-

chyma, or fibrous tissue), the stems are frequently very hard. The fundamental tissues frequently develop a good deal of mucilaginous or slimy matter.

Both stems and roots develop from a three-sided apical cell. The apical cell of the root continually undergoes fission not only parallel to its sides, but also parallel to its base—*i.e.*, at right angles to the axis of the root. The daughter-cells thus cut off (*k, k*, Fig. 257*a*) constitute the root-cap (*pileorhiza*) with which each root-tip is covered.

The leaves, which unfold circinately, are often very large, and in most cases are more or less lobed and divided, frequently becoming several times compound. Their development is slow, the rudiment of the petiole forming one year, and that of the blade the next, while the opening or unfolding does not take place till the following year. The growth is sometimes periodic, as in *Gleichenia* and *Lygodium*. In the

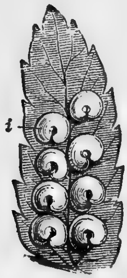


FIG. 258.

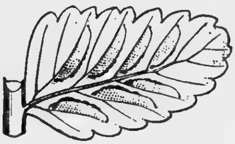


FIG. 259.

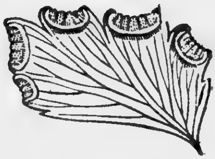


FIG. 260.

Fig. 258.—Under side of a fertile leaflet of *Aspidium Filix-mas*, with eight sori. *i*, the indusium. Magnified.—After Sachs.

Fig. 259.—A leaflet of *Asplenium*, showing the elongated sori, each covered by a laterally placed indusium.—From Le Maout and Decaisne.

Fig. 260.—A leaflet of *Adiantum*, showing the sori covered by indusia formed by reflexions of the margin of the leaflet.—From Le Maout and Decaisne.

latter the leaf eventually becomes greatly elongated, resembling a climbing stem.

The sporangia are usually formed in clusters (*sori*) on the veins, on the under side of the leaves, or upon their margins. The sori may be distinct and rounded or more or less elongated, or they may be confluent over considerable portions of the surface. In some cases the sori are naked (as in Fig. 257*b*), but quite frequently each one is covered by a cellular outgrowth of the leaf, called the *indusium* (Figs. 258, 259, 260). In some cases the indusium is shield-shaped, its short pedicel arising in the midst of the sporangia (Figs. 258 and 261); in others it is more or less elongated, and attached by one of its edges to the side of the sorus (Fig. 259); in still others a portion of the margin of the leaf is reflexed in such a way as to form the covering (Fig. 260). Many other forms are common, and are to be found described in systematic treatises. The sporangia are more or less rounded bodies, usually

borne upon slender pedicels. Morphologically they are trichomes, which undergo a special modification. Each sporangium is at first a two-celled trichome; the lower cell of which develops into the pedicel, while the other becomes divided by partitions parallel to its surface into outer cells, which develop into the sporangial wall, and an inner

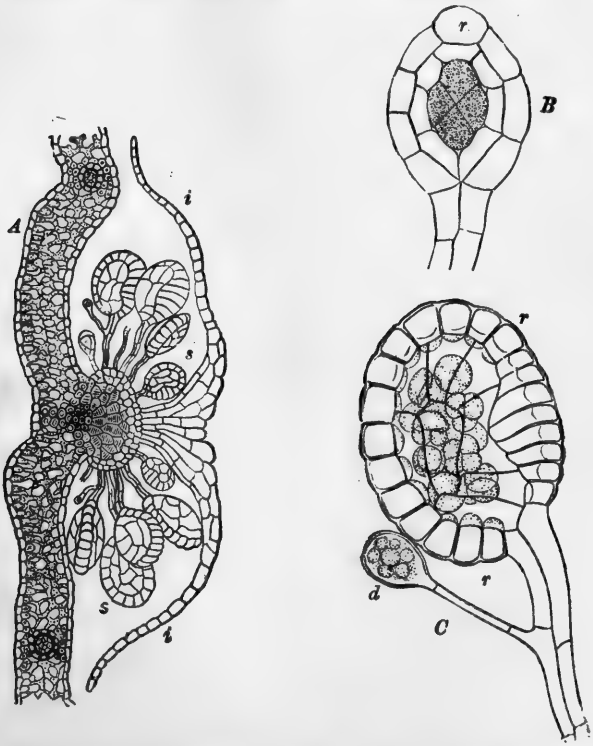


Fig. 261.—*Aspidium Filix-mas.* *A*, a section of a leaf through a sorus; *s*, *s*, the sporangia, borne upon an elevated mass of tissue, the receptacle; *i*, *i*, the indusium, seen in section. *B*, a section of a young sporangium, showing its central cell divided into four; *r*, one cell of the ring, the section being at right angles to its plane. *C*, a sporangium nearly mature, seen laterally; *r*, *r*, the ring of the sporangium; *d*, a glandular hair—in the interior of the sporangium are seen the nearly ripe spores. Magnified.—After Sachs.

tetrahedral cell (the so-called central cell), rich in protoplasm; from the latter a number of spore mother-cells (twelve, according to Reess) are formed, and from each spore mother-cell four spores arise (Figs. 261 and 262). In each sporangium some of the cells of the wall are developed into an elastic ring (*annulus*), which extends part way around the

spore cavity (Fig. 261, *C*, *r*). By the contraction of this ring the ripe sporangium is ruptured and the spores set free. In some cases, instead of forming a ring, the elastic cells are arranged as a group at one side or end of the sporangium.

Six families or suborders of the Ferns may be distinguished, if we take into consideration the characters derived from the asexual generation. They have been arranged as follows : *

1. *Gleicheniaceæ.*—Sporangia sessile, splitting vertically, furnished with a complete horizontal ring. Sori composed of very few sporangia ; receptacle not elevated (Fig. 263). Fronds with very distinct dichotomous branching. Genera two (*Platyzoma* and *Gleichenia*) ; species thirty, mostly confined to the southern hemisphere.

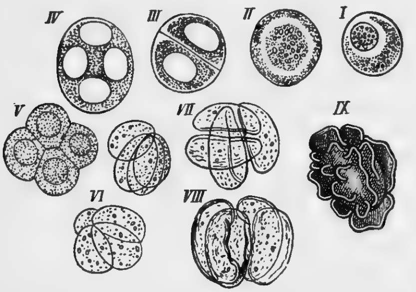


Fig. 262.—Development of the spores of *Aspidium Filix-mas.* *I.*, a mother-cell containing a nucleus ; *II.*, the same after the absorption of the nucleus ; *III.*, the mother-cell, with two large clear nuclei—sometimes a line of separation is evident, as in the figure ; *IV.*, the mother-cell, with four clear nuclei, which appear after the absorption of the two in *III.* ; *V.*, the four daughter-cells (young spores) which form from *IV.* ; *VI.*, *VII.*, *VIII.*, different relative positions of the developing spores ; *IX.*, the perfect spore. × 550.—After Sachs.

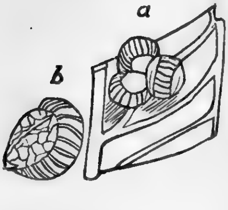
2. *Hymenophyllaceæ.*—Sporangia sessile, splitting vertically, furnished with a complete horizontal ring. Sori composed of numerous sporangia inserted on a long filiform receptacle (Fig. 264). Leaves of filmy texture (usually of a single layer of cells), with pinnate branching. Genera two (*Hymenophyllum* and *Trichomanes*) ; species 150 to 200, mostly confined to the tropics.

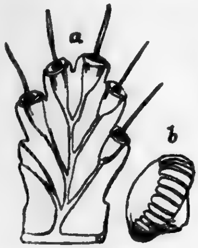
3. *Cyatheaceæ.* — Sporangia nearly sessile, splitting transversely,

* The characters and arrangement of the suborders of ferns are taken from the article " Ferns," by W. T. T. Dyer and J. G. Baker, in the " Encyclopædia Britannica," ninth edition, Vol. IX., p. 104. For a systematic account of the Ferns the student is referred to " Synopsis Filicum : a Synopsis of all Known Ferns," by W. J. Hooker and J. G. Baker, London, 1873. The student may profitably consult the following recently published American works, viz., " The Ferns of North America," by D. C. Eaton, the plates by J. H. Emerton, now being issued in parts ; " Ferns of Kentucky " by John Williamson, 1878 ; " Ferns in Their Homes and Ours," by John Robinson, 1878 ; and " Ferns of the Southwest," by D. C. Eaton, in Lieut. Wheeler's " Report upon U. S. Geographical Surveys West of the One Hundredth Meridian," Vol. VI., 1878 ; Underwood's " Our Native Ferns, and their Allies," 1888.

furnished with a usually incomplete, nearly vertical, or rather oblique ring. Receptacle prominent, barrel-shaped (Fig. 265). Tree-ferns. Genera three (*Cyathea*, *Hemitelia*, and *Alsophila*); species 150, mostly tropical and subtropical.

4. *Polypodiaceæ.* — Sporangia stalked, splitting transversely, furnished with a usually incomplete vertical ring. Receptacle not prom-





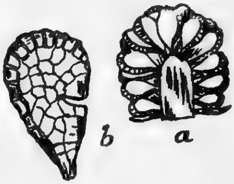


FIG. 263. FIG. 264. FIG. 265.

Fig. 263.—Portion of a leaf of *Gleichenia*, with a sorus, *a*; *b*, a sporangium.—After Hooker.

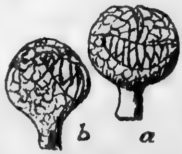
Fig. 264.—Portion of a leaf of *Trichomanes*, *a*, with five sori; *b*, a sporangium.—After Hooker.

Fig. 265.—Vertical section of a sorus, *a*, of *Alsophila*, showing the cylindrical receptacle; *b*, a sporangium.—After Hooker.

inent (Figs. 257*b* to 261). Genera fifty (*Acrostichum*, *Polypodium*, *Adiantum*, *Pteris*, *Asplenium*, *Scolopendrium*, *Aspidium*, *Cystopteris*, etc.); species 2000, widely distributed throughout the world.

5. *Osmundaceæ.*—Sporangia stalked, splitting vertically, furnished with only a faint horizontal bar, instead of a ring (Fig. 266). Genera two (*Osmunda* and *Todea*); species ten to twelve, widely distributed in north and south temperate regions.

6. *Schizæaceæ.* — Sporangia sessile, splitting vertically, crowned by a complete small annular horizontal ring (Fig. 267). Genera five (*Schizæa*, *Anemia*, *Lygodium*, etc.); species sixty, mostly natives of the warm regions of America and Asia.



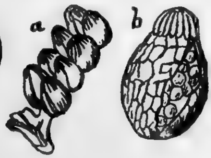


FIG. 266 FIG. 267.

Fig. 266. —Two sporangia of *Osmunda*; *a*, with the rudimentary ring seen in front view; *b*, with the ring seen in profile.—After Hooker.

Fig. 267.—Lower portion of a fertile pinna, *a*, of *Schizæa*; *b*, a sporangium.—After Hooker.

Economically the true Ferns are of comparatively little value. The pulpy interior of the stem of a tree-fern (*Cyathea medullaris*) growing in the Pacific islands furnishes an important article of food to the natives. In Australia the underground stems of *Pteris aquilina* supply an indifferent food. A few species are of doubtful value as astringent medicines. The long woolly hairs of certain species of

Dicksonia growing in the Sandwich Islands constitute the substance known as Pulu, used somewhat in upholstery. Many of the species are now largely grown as ornaments.

Ferns first appeared in the Devonian, in which period no less than twelve genera belonging to extinct families were represented. In the Carboniferous the genera and species were exceedingly numerous, after which they decreased to the present. Many Tertiary genera extend to the present, and are now represented by living species.

Order Marattiaceæ, the Ringless Ferns. The prothallia of the ringless Ferns are thick, fleshy, and dark green in color. They bear antheridia in depressions upon both surfaces, and in these are produced spermatozoids bearing much resemblance to those of true Ferns. The archegonia are also deeply sunken in the tissue of the prothallium, and, according to McNab, resemble those of the Rhizocarpeæ.

The asexual generation bears a close resemblance to that of true

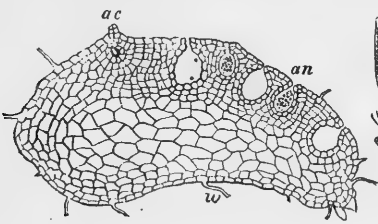


Fig. 268.

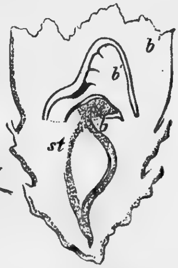


Fig. 269.

Fig. 268.—A prothallium of *Botrychium Lunaria*, in longitudinal section. *ac*, an archegonium; *an*, an antheridium—near to it are others, one not yet mature, and three empty ones; *w*, root-hairs. × 50.—After Hofmeister.

Fig. 269.—A longitudinal section of the lower part of a young plant of the same, dug up in September. *st*, stem; *b*, *b'*, *b''*, leaves. × 20.—After Hofmeister.

Ferns. The plant-body is usually large; its stem is generally upright, short, thick, and unbranched; the leaves are circinately developed, as in true Ferns, and are mostly very large, with pinnately or palmately divided laminæ; they are provided with stipules, and in their petioles is found the first collenchyma. The stem develops from a three-sided apical cell, but the root is provided with a group of cells, as in the Phanerogams.

The sporangia occur on lateral veins upon the under side of the leaves, and are usually confluent into one body, the sorus (often called erroneously the sporangium). In *Angiopteris*, however, the sporangia are distinct. The spores develop from many mother-cells in each sporangium, instead of from one, as in true Ferns.

The Marattiaceæ are essentially tropical, extending somewhat into the warmer parts of the temperate zones. Four genera are known, viz., *Danæa*, restricted to tropical America; *Kaulfussia* and *Angiopteris*,

found in the tropical regions of the eastern hemisphere; and *Marattia*, which is represented in the New and Old World. The whole number of species probably does not exceed twenty-five.

The oldest members of this order occur in the Permian strata.

Order Ophioglossaceæ, the Adder-Tongues. The prothallia of these fern-like plants are thick masses of parenchyma, which are destitute of chlorophyll; they develop underground, and are difficult to study, hence they are known for but few of the species. In *Botrychium Lunaria*, according to Hofmeister,* the prothallium is "an oval mass of firm cellular tissue, whose larger diameter does not exceed a millimetre (one twenty-fifth of an inch), and is often less" (Fig. 268). He discovered them in the ground at a depth of from two and a half to seven and a half centimetres (one to three inches). The antheridia occur for the most part upon the upper surface, and the archegonia upon the lower.

The mature plant (asexual generation) consists of a short erect underground stem, which bears annually one or more stipulate and erect (*i.e.*, not circinate)† leaves (Fig. 269, b' and b'', and Fig. 270). The leaf is usually divided into two portions, one of which is green and expanded (Fig. 270, *b*), while the other is contracted into a spore-bearing organ (Fig. 270, *f*); in some cases each segment is simple, while in others it is one or more times compound.

The spores of the *Ophioglossaceæ* are produced from mother-cells developed in the tissue of the fertile segment of the leaf; hence the so-called sporangia of this order are morphologically quite different from those of true Ferns.

Fig. 270.—Plant of *Botrychium Lunaria*, nat. size. *st*, *st*, the short stem; *w*, roots; *bs*, the leaf stalk; *x*, point where the leaf branches into the sterile part (*b*) and the fertile or spore-bearing portion (*f*).—After Sachs.

* "On the Germination, Development, and Fructification of the Higher Cryptogamia," etc., by Dr. Wilhelm Hofmeister. Translated by Frederick Currey, London, 1862.

† The vernation of our species of *Botrychium* is well worked out in

The stems are developed from a triangular apical cell, while the roots, like those of *Marattiaceæ*, possess no apical cell, but a group of cells instead. The fibro-vascular bundles are arranged in a cylinder (a circle in cross-section), and they form a network by their anastomosing with each other. According to De Bary, they belong to the "collateral" series.

These plants are usually of small size, rarely exceeding 30 centime-

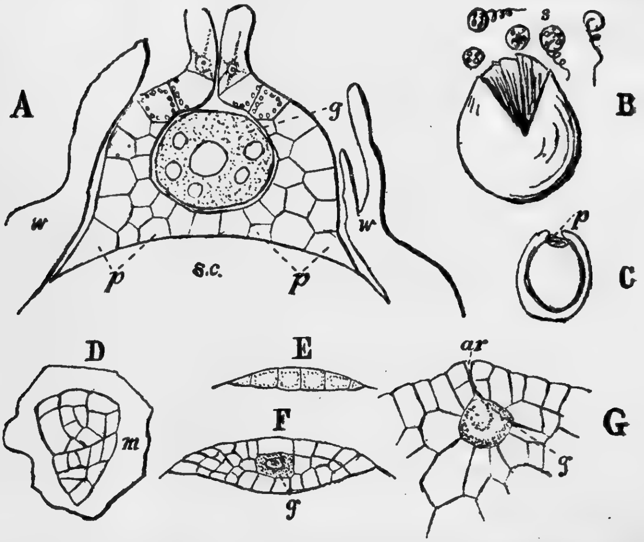


Fig. 271.—*A*, vertical section of an archegonium and the rudimentary prothallium of *Pilularia globulifera*; *w*, *w*, part of the ruptured wall of the macrospore; *p*, *p*, the rudimentary prothallium, merging above into the archegonium; *g*, the germ-cell ready for fertilization; *sc*, the cavity of the macrospore. × 500. *B*, a microspore of the same burst open and allowing the escape of sperm-cells. *s*, from which spermatozoids are escaping. × 600. *C*, longitudinal section of a macrospore of *Salvinia natans* at the commencement of germination; *p*, the young prothallium. × 30. *D*, a very young prothallium of the same, detached, with a fragment of the inner spore-membrane (*m*) adhering to it—top view. × 200. *E*, a vertical longitudinal section of *D*. × 200. *F* a similar section of a more advanced prothallium of the same; *g*, the young germ-cell. × 200. *G*, vertical section of an unfertilized archegonium of the same, surrounded by cells of the prothallium; *g*, germ-cell; *ar*, canal of the archegonium. × 300.—After Hofmeister.

tres (1 foot) in height; in one Ceylonese species (*Ophioglossum pendulum*) the slender pendent leaves are sometimes, according to Hooker, nearly three metres long (15 feet).

There are three genera, viz., *Ophioglossum*, *Botrychium*, and *Helminthostachys*; the latter is confined to the southern hemisphere, the others

---

G. E. Davenport's paper, *Vernation in Botrychia*, in the *Bulletin of the Torrey Botanical Club*, 1878; it is illustrated by figures.

are cosmopolitan. All told, there are probably not more than eighteen or twenty distinct species, of which we have six within the limits of the United States.

A species of *Ophioglossum* has been discovered in the Tertiary strata.

Order Rhizocarpeæ, the Pepperworts. The prothallia of the Rhizocarps are diœcious, and are developed from two kinds of spores (the *macrospores* and *microspores*, to be more particularly described below). The antheridia are simple, and consist of small, few-celled outgrowths from the germinating microspore (in *Salvinia* and *Azolla*), or of the transformed contents of the microspore (in *Marsilia* and *Pilularia*, Fig. 271, *B*). The spermatozoids are spirally coiled, and in the two last-named genera are produced in definite numbers (thirty-two) in each antheridium. The prothallia which produce archegonia are small, and barely attain a size large enough to protrude through the ruptured wall of the macrospore (*p*, *p*, Fig. 271, *A*). The archegonia resemble those of true Ferns, but are more sunken in the tissues of the prothallia (Fig. 271, *A* and *G*). After fertilization the germ-cell undergoes division, and gives rise directly to a leafy stemmed plant, the asexual generation, provided with roots (except in *Salvinia*). The stem is horizontal, and floats upon the water or runs through the mud at the bottom of shallow water. The leaves are circinately developed, and are simple or quadrifid (Fig. 272). The stem and root develop from an apical cell, which is two or three-sided in the stem, and triangular in the root.

FIG. 272.

FIG. 273.

Fig. 272.—Plant of *Marsilia salvatrix*. *K*, apex of the stem; *b*, *b*, leaves; *f*, *f*, *f*, the fruits springing from the petioles at *x*. One half nat. size.—After Sachs.

Fig. 273. — Longitudinal section through three fruits (the fertile apices of a water-leaf) of *Salvinia natans*. *i*, *i*, two fruits containing microsporangia; *a*, one with macrosporangia. × 10. —After Sachs.

The sporangia, which are usually of two kinds, are produced in "fruits" or receptacles, which are modified parts of leaves. These

fruits are one-celled in *Salviniaceæ,* and several-celled in *Marsiliaceæ.* In *Salvinia* (Fig. 273) the microsporangia are small and numerous, and are contained in separate fruits from the macrosporangia, which are few in number; each of the former contains many microspores, and the latter a single macrospore (by the abortion of three, as four are formed at first). In *Marsilia* and *Pilularia* the two kinds of spores occur in the same fruit, and in the former in the same sporangium.

Four genera are known; these are arranged under two suborders or families, the *Salviniaceæ,* which includes *Salvinia* and *Azolla,* and the *Marsiliaceæ,* which includes *Marsilia* and *Pilularia.* The whole number of species is sixty-four, of which forty belong to *Marsilia,* the others being unequally divided between the remaining genera. All the species are of small size, rarely exceeding a few centimetres in height; they grow in ditches and other wet places. Half a dozen species occur in the United States.

Rhizocarps have been found as fossils in the Secondary (Jurassic) and Tertiary strata.

§ III. CLASS LYCOPODINÆ.*

491.—The plant-body of the asexual generation consists of a solid, dichotomously branched, leafy, and generally erect stem. The leaves, which have a central fibro-vascular bundle, or midrib, are small, simple, sessile, and imbricated, and usually bear a considerable resemblance to those of Mosses. The roots are mostly slender and dichotomously branched.

The Lycopodinæ are for the most part terrestrial perennials. They are usually of small size, rarely exceeding a height of 15 or 20 centimetres (6 or 8 inches).

492.—The spores of the Lycopodinæ are produced in sporangia which are generally (if not always) axillary appendages of the leaves. In four of the genera (*Lycopodium, Psilotum, Tmesipteris,* and *Phylloglossum*) the spores are of one kind; while in the two remaining genera (*Selaginella* and *Isoetes*) they are of two kinds, the macrospores and the microspores.

493.—The prothallium or sexual generation is scarcely known in the isosporous genera; it appears, however, to be a thickish mass of tissue, which develops underground, and

* Sachs calls this class the *Dichotomæ,* but as long as we have the *Equisetinæ* and *Filicinæ,* we may, for the sake of uniformity, retain the old name given above.

bears both kinds of sexual organs. In the heterosporous genera the macrospores produce small prothallia, which project slightly through the ruptured spore-wall, and upon these several or many archegonia are formed; the microspores produce very small rudimentary prothallia, each of

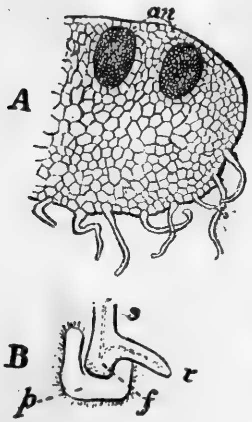


Fig. 274.

Fig. 275.

Fig. 274.—*A*, longitudinal section of a young prothallium of *Lycopodium annotinum; an*, two antheridia, not mature—upon its lower surface are seen the root-hairs. × 150. *B*, longitudinal section of a prothallium, *p*, of the same, after germination of the young plant; *s*, stem of young plant; *r*, its young root; *f*, the foot, or portion of the young plant which remains in contact with the prothallium. Slightly magnified.—After Fankhauser.

Fig. 275.—Plant (asexual generation) of *Lycopodium clavatum;* horizontal stem with roots and leaves, the erect branch bearing fertile spikes, *s*. One half natural size. —After Prantl.

which bears a single antheridium, in which there are developed a few spermatozoids.

494.—Three orders of Lycopodinæ may be distinguished, as follows:

I. Isosporeæ.—Spores of one kind; no ligules.

Order 1. Lycopodiaceæ, with small leaves, commonly moss-like.

II. Heterosporeæ.—Spores of two kinds; ligules present.

Order 2. Selaginellæ, with small moss-like leaves.

Order 3. Isoeteæ, with elongated grass-like leaves.

Order Lycopodiaceæ.—The prothallium is known only in one case, viz., *Lycopodium annotinum.* It was discovered underground by Fankhauser in 1872, who described it* as a yellowish white, irregularly lobed body, sparingly furnished on its under surface with small root-hairs (Fig. 274, *A*). In its upper surface the prothallium bears antheridia, which are deeply sunken in its tissue (*an*, Fig. 274, *A*); the spermatozoids, which are numerous, are stout and slightly twisted. The archegonia were only seen after the young plants had grown considerably (Fig. 274, *B*); they are likewise developed upon the upper surface of the prothallium, and appear to bear a considerable resemblance to those of the *Ophioglossaceæ.*

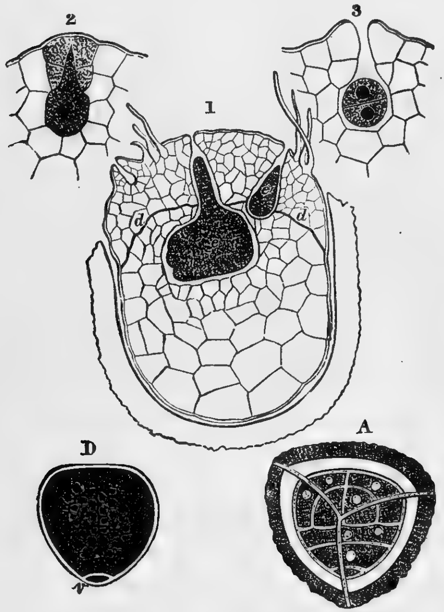


Fig. 276.—Germination of the spores of *Selaginella.* 1, longitudinal section of a macrospore of *S. Martensii*; above the line *d* is the prothallium, below it the "endosperm;" *e*, *e'*, two embryos, the larger one with its suspensor projecting into the neck of the archegonium; at the left of the larger embryo is a young archegonium; several root-hairs are also shown. 2, a young archegonium of the same species, not yet open. 3, an archegonium of the same species, with the germ-cell fertilized and divided into two. *A*, a microspore of *S. caulescens*, rendered transparent, showing the division of the contents into the primordial cells; the small lower cell is the rudimentary prothallium. *D*, later stage of the same, showing the large antheridium filled with sperm-cells; *v*, the rudimentary prothallium. All magnified.—After Pfeffer.

The young plant which results from the growth of the fertilized germ-cell is quite simple, but it soon takes on the form of the mature plant. The leaves are crowded in *Lycopodium*, but are less so in the other genera. In many species the sporangia are borne in the axils of the ordinary leaves, but in others the leaves which bear sporangia are collected into cone-like or spike-like structures, which terminate certain branches (Fig. 275). The sporangia are more or less globose bodies, which are short-stalked or sessile; they contain large numbers of small spores, which escape by an apical slit in the sporangium.

* J. Fankhauser: "Ueber den Vorkeim von Lycopodium," in *Botanische Zeitung*, 1873, No. 1.

Four genera belong to this order, viz., *Lycopodium*, which is common in the wooded portions of the United States; *Psilotum*, found in Florida; *Tmesipteris* and *Phylloglossum*, of Australia. The species number from 115 to 120, of which about 100 belong to the genus *Lycopodium*.

The spores of *Lycopodium clavatum* are gathered in Europe and sold for various minor uses. Many species have a high ornamental value.

This order was represented in the Devonian by species of *Arctopodium*. In the Carboniferous the genus *Lycopodium* first appeared.

The closely related extinct order Lepidodendreæ first appeared in the Devonian, in which it was represented by two known species of *Lepidodendron*; in the Carboniferous this genus was represented by sixty or more species, many of gigantic size, and the order by many other genera—e.g., *Lepidophloios*, *Lepidostrobus*, *Halonia*, etc. In the Permian this order became extinct.

Another order—the Sigillarieæ—was represented by many species of *Sigillaria* in the Carboniferous period. Like the preceding, this order became extinct in the Permian.

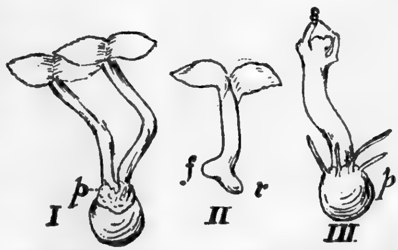


Fig. 277.—*I.*, two young plants of *Selaginella Martensii* growing from the same spore; at the top of the spore may be seen the projecting prothallium, *p*. *II.*, a young plant drawn out of the spore, showing the foot, *f*, on the left below, and the young root, *r*, on the right. *III.*, a young plant whose first leaves (cotyledons) have been removed, leaving only their stipules, *s*; between the latter is seen the dichotomously dividing *punctum vegetationis*; *p*, the prothallium isolated from the spore. *I.* × 5; *II.* × 3; *III.* × 30.—After Hofmeister.

Order Selaginellæ.—The prothallia are diœcious. Those which develop from the macrospores consist of a concavo-convex many-celled structure, which develops upon, and has its concave side applied to, the convex surface of the spore. Upon its convex surface, which protrudes through the ruptured wall of the spore, are a few root-hairs and many deeply sunken archegonia (Fig. 276, 1, 2, 3). The microspores develop only the smallest rudiments of prothallia. In germination a single cell (*v*, Fig. 276, *D*) is first of all cut off; this undergoes no further change, and is doubtless to be regarded as the prothallium. The remainder of the spore becomes divided in a regular way into a few large primordial cells (Fig. 276, *A*), and from these great numbers of sperm-cells are produced (Fig. 276, *D*).

After fertilization the germ-cell divides at right angles to the axis of the archegonium (Fig. 276, 3); from the upper cell so formed a *suspensor* is developed (Fig. 276, 1), while the lower develops into the embryo. The embryo, by its rapid growth, comes eventually to occupy

the cavity of the spore itself, in which, by bending upon itself, it lies at right angles to the axis of the archegonium. The new plantlet bears some resemblance to the embryo in the Dicotyledons; it has an elongated stem, bearing at its summit two small leaves (cotyledons), having between them a growing bud (plumule); at the lower end of the stem there is a rudimentary root, and the structure known as the foot, which is common to all Pteridophytes (Fig. 277, *II.*).

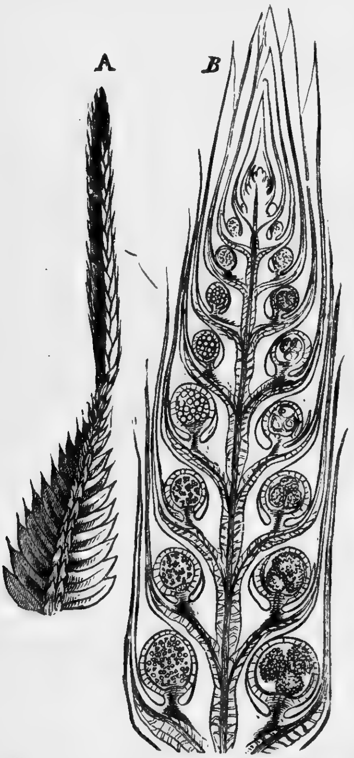


Fig. 278.—*A*, a fertile branch of *Selaginella inæquifolia*, with the quadrangular spore-bearing spike at the apex; *B*, vertical section of the spike, showing the microsporangia containing microspores on the left, and the macrosporangia with macrospores on the right.—*A* × 2; *B* × 15.—After Sachs

The young plant grows from the spore with its cotyledons foremost (Fig. 277, *I.* and *III.*); this is only possible by the great bending of the embryo upon itself, for at first its cotyledonary extremity points directly toward the centre of the spore—*i.e.*, away from the opening in the spore-wall. Usually but one plantlet grows from each prothallium but occasionally two or more may be developed (Fig. 277, *I.*)

The adult plant of the asexual generation is densely leafy throughout. The leaves are small, moss-like, and are generally placed in four rows, of which two opposite ones are composed of large leaves, and the two intermediate ones of small leaves. Each leaf has a small scale-like body, the ligule, on its upper surface at its base. The sporangia occur singly in the axils of certain leaves, generally in those which form the narrower "fruiting spikes" (Fig. 278, *A*). Macrosporangia, containing four macrospores in each, usually occur in some definite portion of the spike, as nearer the base, or upon one side (Fig. 278, *B*). The microsporangia contain many microspores, and usually also occupy definite positions in the spike.

But one genus, *Selaginella*, is known in this order; it includes 334 species of mostly delicate plants, which are mainly tropical, not more

than six or seven species occurring within the limits of the United States. Many are cultivated as ornaments.

Order Isoeteæ, the Quillworts. The prothallia of the Isoeteæ are diœcious, and resemble closely those of *Selaginella.* The macrospores give rise to small prothallia, which project through the triangular slit in the spore-wall, and bear several or many sunken archegonia (Fig. 279). The microspores, in their germination, first cut off a small cell (*v*, Fig. 280, *A* to *C*), which, as in *Selaginella,* represents the prothallium; the remainder of the spore contents becomes divided into four cells (the primordial cells), and these give rise to the sperm-cells (Fig. 280, *A* to

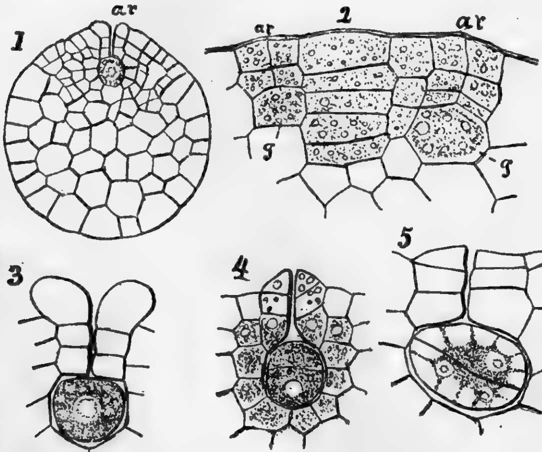


Fig. 279.—1, Longitudinal section of a prothallium of *Isoetes lacustris,* four weeks after sowing the spore; *ar*, an archegonium. 2, a portion of the apex of a prothallium cut through longitudinally, with two archegonia, *ar*, *ar*, still in process of development; *g*, *g*, the germ-cells of the archegonia. 3, longitudinal section of an archegonium ready for fertilization. 4, longitudinal section of a fertilized archegonium, showing the germ-cell transversely divided. 5, a section similar to the last; in the lower cell of the embryo-rudiment preparation for division has been made by the appearance of two nuclei. 1 × 40; 2 and 3 × 300; 4 and 5 × 400.—After Hofmeister.

C). The spermatozoids are elongated and provided with cilia at both ends (Fig. 280, *f*).

The germ-cell, after fertilization, undergoes transverse division (Fig. 279, 4 and 5), as in *Selaginella,* and its subsequent development is essentially the same.

The adult plant of the asexual generation consists of a very short, thick, tuber-like stem, which bears numerous long, narrow, grass-like leaves, which are sheathing at the base. There are also numerous roots. The sporangia are produced in grooves on the inner side of the bases of the leaves; those attached to the outer leaves contain macro-

spores, while the interior ones contain microspores. Both macrospcres and microspores are produced in great numbers in the sporangia.

The Quillworts are for the most part aquatic plants; they are found chiefly in the north temperate and warm regions. The species, of

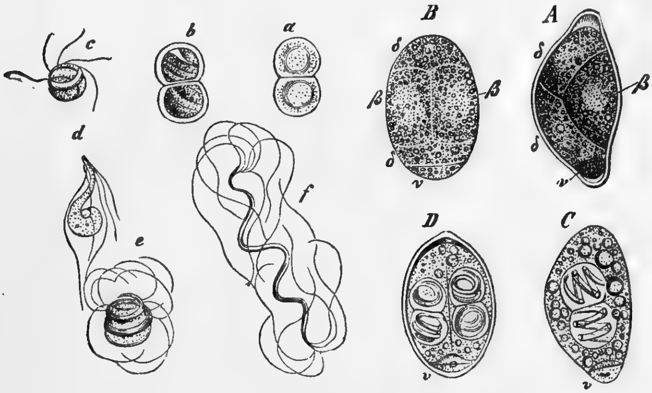


Fig. 280.—Germination of the microspores of *Isoetes lacustris*. *A*, a microspore, side view. *B*, the same, ventral view; the spore contents have divided into a few cells, of which *v* in each figure represents the rudimentary prothallium; β, β are the ventral, and δ δ the dorsal cells. *C*, a side view of microspore; the four cells, β, β, δ, δ, have disappeared, and spermatozoids have formed. *D*, ventral view of *C*; *a* to *f*, development of spermatozoids. *e* and *f* × 700, the others × 580.—After Millardet.

which there are from forty to fifty or more, all belong to the single genus *Isoetes*;* we have representations of about fourteen within the United States.

Two species of *Isoetes* occur as fossils in the Tertiary (Miocene).

---

* The North American species of Pteridophytes are well described in "Our Native Ferns and their Allies," by L. M. Underwood. (Holt, 1888.)

CHAPTER XX.

PHANEROGAMIA, OR ANTHOPHYTA.

§ I. General Characters.

495.—In this Division the alternation of generations which is so well marked in Bryophytes and in most Pteridophytes disappears. We have seen that in the higher Filicinæ and Lycopodinæ there is a great reduction in the size and importance of the prothallium (the sexual generation); in *Equisetaceæ* and *Filices* it is a large growth, which soon becomes entirely independent of the spore from which it originates; in *Ophioglossaceæ* and *Lycopodiaceæ* it is of considerable size, but it is less capable of leading an independent existence; in *Rhizocarpeæ* and *Selaginellæ* it is reduced to a small outgrowth of the spore; and in *Isoeteæ* the reduction is still greater, the small prothallium being little more than the transformed spore contents.

With the decrease in the structural importance of the prothallium in these orders of the Pteridophyta, there is a noticeable increase in the differentiation of the spore before its separation from the parent plant; thus in the three last-named orders the spores have differentiated into (1) small ones, microspores, which are strictly male as to their functions, and (2) larger ones, macrospores, which are as strictly female.

496.—In the Phanerogamia the changes begun in the Pteridophyta proceed a step further. The differentiation into male and female organs of reproduction is carried back far beyond the formation of the microspores (pollen grains) and macrospores (embryo sacs); the macrospore does not sever its connection with the parent plant, but continues to be nourished by it until after the embryo is formed; and as

a consequence of its maintaining its structural connection with the parent plant, the prothallium (endosperm) is but feebly developed. The prothallium is essentially, as to its function, a nourishing structure, which is rendered necessary in the Pteridophytes by the fact that the reproductive bodies separate from the parent plant before they are ready for fertilization; and just as this separation is delayed, or, in other words, just as the parent plant bestows more care upon the bodies which are to give rise to the embryo, so the prothallium is less necessary, and, being less necessary, is less developed. Thus we find a much smaller prothallium in the heterosporous orders of Pteridophytes than in the isosporous ones, and in Phanerogams, where parental care extends until after the formation of the embryo, there is generally only the smallest rudiment of a prothallium.

497.—The leafy plant (which corresponds to the asexual generation of the Pteridophytes) produces two kinds of reproductive cells, viz., pollen grains and embryo sacs, the homologues respectively of microspores and macrospores. The pollen grains are for the most part single cells, which develop from mother-cells in the interior of phyllome structures (modified leaves); they soon become free, and are then more or less spherical in shape; they have two coats, an outer thick one, the extine, and a delicate inner one, the intine, and they contain a granular protoplasm, in which oil drops and starch granules generally occur. The embryo sacs are thin-walled cells which arise axially in the ovules, structures which appear to be homologous to the macrosporangia of Pteridophytes; they do not become free, but continue to be in organic connection with the cells of the surrounding tissues. Each embryo sac develops in its interior a larger or smaller mass of cells, the endosperm, which is the homologue of the prothallium, and in which nourishing matters are deposited; it also develops one or more germ-cells, the homologues of the germ-cells of the archegonia in Pteridophytes.

498.—The portions of the plant-body which produce pollen grains and embryo sacs are in general considerably modified; thus the axis is generally short, the leaves delicate or

otherwise different from foliage leaves, and containing little or no chlorophyll ; they are usually of some other color than green, from the presence of soluble coloring-matters in their cells. These modified parts, together with the organs more immediately connected with the male and female reproductive cells, constitute what is known as *the flower*.

499.—The ovule, in its development, becomes surrounded by one or two thin cellular coats, which grow from its base, and almost completely enclose it, a little orifice only, the *micropyle*, being left at its apex. In the lower Phanerogamia (the Gymnosperms) the ovule enclosed in its single (rarely double) coat is otherwise naked, while in the higher classes—viz., the Monocotyledons and Dicotyledons—it is enclosed within the cavity of the ovary, a phyllome structure, or, as it is commonly described, a modified leaf, which is folded involutely so as to form a cavity.

500.—In the fertilization of the germ-cell there are no spermatozoids developed ; instead of producing these, the pollen grain develops a long slender tube, the pollen tube, which penetrates the tissue of the ovule, and comes in contact with the germ-cell in the embryo sac. The result of fertilization is always the formation of a suspensor (sometimes called the pro-embryo) essentially like that in the *Selaginellæ* and *Isoeteæ*, and, at the lower end of this, an embryo, consisting of a short stem, bearing generally one or more rudimentary leaves (*cotyledons*) at one extremity, and a rudimentary root at the other. The embryo grows at the expense of the endosperm, upon which it gradually encroaches, and in many orders entirely displaces. While the embryo is forming, the ovule becomes greatly enlarged, and its outer coat generally much thickened and hardened ; it is now called the seed, and soon separates at its base from the parent plant.

501.—After a longer or shorter period of rest the seed germinates, the root and stem elongate, and the former pushes out through the micropyle ; in those seeds in which much of the endosperm remains,* or in which the cotyle-

* Seeds which contain endosperm are, in the ordinary descriptive

dons are greatly thickened, the latter remain for some time inside of the seed ; in other cases, however, they soon withdraw themselves, and become expanded as the first leaves of the plantlet. The young plant is quite simple at first, but, with the development of each succeeding internode, it becomes more like the adult plant.

502.—The three tissue systems are generally well developed in Phanerogamia. The epidermis is copiously supplied with stomata, and itself consists of one or (rarely) more layers of cells, whose external walls are generally somewhat thickened, and whose cell contents rarely contain chlorophyll. Trichomes of various forms are abundantly developed. The fibro-vascular bundles are of the form called by De Bary collateral bundles, the only exception being the first formed one in the root, which is of the radial type. The bundles are symmetrically arranged in the stem, through which they pass vertically parallel to each other. They are mostly common—*i.e.*, they extend from the leaves into the stem ; but some are strictly cauline—*i.e.*, they are found only in the stems and have no connection with the leaves. All the kinds of tissues, with the exception of collenchyma, may occur in the bundles ; but they are mainly made up of tracheary, sieve, and fibrous tissues. In the larger perennials, as the trees, the great mass of tissue in the woody stems is principally made up of the tracheary and fibrous tissues of the fibro-vascular bundles. In succulent plants, especially those growing in water, the bundles are usually smaller and more simple, being sometimes reduced to a thread of tracheary or sieve tissue.

In the fundamental tissues parenchyma, in its various forms, is by far the most common. The hypodermal portions are frequently composed of collenchyma or sclerenchyma. Laticiferous tissue is common in the fundamental system of certain orders.

503.—By far the greater number of Phanerogams are chlorophyll-bearing plants, comparatively few only being

---

books, said to be albuminous, while those in which it is wanting are said to be exalbuminous.

parasitic or saprophytic. They range from minute plants one or two centimetres in height, and living but a few days or weeks, to enormous trees, which continue to grow for many hundred years, and which attain a diameter of ten, and a height of one hundred metres.

504.—The Phanerogams are separable into two classes, as follows :*

Class I. Gymnospermæ (the *Archespermæ* of Strasburger). The ovules are not enclosed in an ovary. The endosperm arises before fertilization, and forms rudimentary archegonia ("corpuscula"), in which the germ-cells originate. The contents of the pollen grains divide before the growth of the pollen tube, forming a rudimentary prothallium, much as in *Selaginellæ* and *Isoeteæ*.

Class II. Angiospermæ (the *Metaspermæ* of Strasburger). The ovules are enclosed in an ovary. The endosperm is formed after fertilization. The contents of the pollen grain remain undivided before and during the growth of the pollen tube.

Sub-Class Monocotyledones.—The first leaves produced by the embryo (the cotyledons) are alternate ; the endosperm is usually large and the embryo small.

Sub-Class Dicotyledones.—The first leaves of the embryo form a whorl of two (*i.e.*, they are opposite); the endosperm is very often rudimentary or entirely wanting, and the embryo is generally large.

§ II. Class Gymnospermæ.

505.—The plants of this class have solid stems, which bear in most cases small, simple, narrow leaves having a parallel venation. The xylem portions of the fibro-vascular bundles of the stem are closely compacted into a single dense woody cylinder, which is surrounded by a looser mass of tissues, the so-called bark, composed of the united phloëm portions of the bundles. The woody cylinder increases its

* This is essentially Sachs' arrangement, in his "Lehrbuch," 4te Auf. The terms Archespermæ (from the Greek ἀρχή, beginning, and therefore properly Archespermæ, instead of Archispermæ) and Metaspermæ (from μετά, after or later) are those proposed by Strasburger : "Die Coniferen und die Gnetaceen," 1872, p. 239.

diameter centrifugally, and the sheathing envelope of bark centripetally, by the growth of new tissues between these two portions.

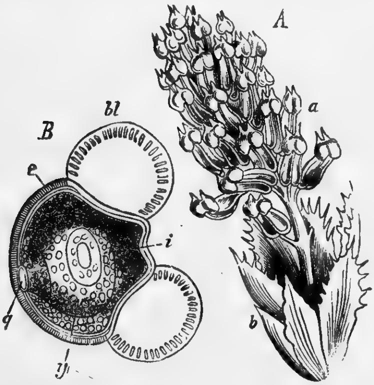


Fig. 281.—*A*, a male flower of *Abies pectinata*; *b*, bracts; *a*, stamens. *B*, pollen grain; *e*, extine, with its large vesicular protrusions, *bl*; *i*, intine; *y*, cell in the interior of the pollen grain developing the pollen tube; *q*, basal cell attaching *y* to the wall of the grain. × 300 —*A* after Sachs; *B* after Schacht.

Gymnosperms are all terrestrial, chlorophyll-bearing plants; none are aquatic, and none are parasitic. Most of them are large trees, a few only being shrubs or undershrubs.

506. — The flowers of Gymnosperms are much simpler than those of the remaining Phanerogams. They are always diclinous —*i.e.*, the male and female organs are in different flowers. They consist essentially of one or more variously shaped pollen-producing organs (stamens) on the one hand, and naked ovules on the other; both kinds of organs are in most cases in structural connection with scale-like bodies, which serve as accessory organs of reproduction.

507. — The male flower in *Abies pectinata* consists of an elongated axis, upon which are borne a large number of spirally arranged stamens (*a*, Fig. 281, *A*). Each stamen is morphologically a phyllome, which is here modified into a body consisting of a short stalk (*filament*) supporting two pollen sacs (the anther). The pollen grains are developed from mother-cells, each of the latter giving rise to four grains. The pollen-mother-cells themselves arise from the interior parenchyma of the stamen by the differentiation and enlargement of cer-

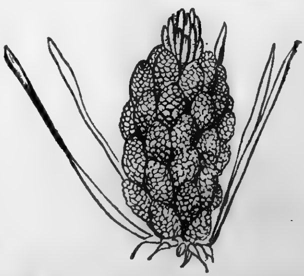


Fig. 282.—A catkin or spike of the male flowers of *Pinus sylvestris*.—From Le Maout and Decaisne.

tain cells. Each pollen grain is at first a single cell, but by the time it escapes from the anther it is a several-celled body, by the formation of partitions within its cavity (*q*, *y*, Fig. 281, *B*). The daughter-cells thus formed are doubtless the homologues of the prothallium of the higher Pteridophytes. Each mature grain has a double wall, of which the outer one (the *extine*) is hard and thick, while the inner one (*intine*) is thin and delicate (*e* and *i*, Fig. 281, *B*). In this case (as indeed is common) there are two vesicular protrusions of the extine (*bl*, Fig. 281, *B*), which give the grain the appearance externally of being three-celled.

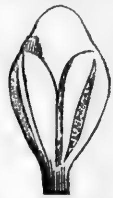


Fig. 283. — A stamen from the flower of *Pinus sylvestris*, showing the two pollen sacs. Magnified. —From Le Maout and Decaisne.

Fig. 284. — *A*, male flower of *Taxus baccata*; *a*, the pollen sacs. *B*, a stamen, seen from below. *C*, a piece of a foliage-shoot, *s*, with a leaf, *b*, in whose axil is a scaly axis (the female flower), which is terminated by an ovule, *sk*; *s*, the scales. *D*, longitudinal section of the female flower in *C*, more magnified; *i*, integument or coat of ovule; *kk*, the body or "nucleus" of the ovule; *m*, aril; *x*, a rudimentary axillary ovule. (☞ By an error of the engraver the hair line from *x* is carried about 1 mm. too high in the figure.) *E*, longitudinal section of an older ovule, but before fertilization; *i*, integument or coat of the ovule; *e*, endosperm (drawn showing the cells); *kk*, the body or "nucleus" of the ovule (drawn plain, *i. e.*, not showing the cells); *ss*, upper scale leaves; *m*, rudimentary aril between the upper scale leaves and the ovule. All the figures magnified.—After Sachs.

The male flowers of *Pinus sylvestris* are collected into catkins or spikes (Fig. 282). They are structurally similar to those described above. The stamens are short and broad, and each bears on its back or outer surface two elongated pollen sacs (Fig. 283). The pollen grains are similar to those of *Abies*.

In *Taxus baccata* the male flower differs from those described above only in the shape of the stamens, which are peltate and lobed (Fig. 284, *B*). They bear attached to the under surface three to eight pollen-sacs, which contain many globose pollen grains.

These examples will serve to illustrate the general structure of the male flower, which, with minor variations,

is in nearly all the class essentially like the ones described. The exceptions, which are in the order Gnetaceæ, will be described further on. It may be pointed out here that in passing up through the three orders of the class, the pollen sacs, which in the first resemble sporangia, become more nearly like the anthers of the Monocotyledons and Dicotyledons.

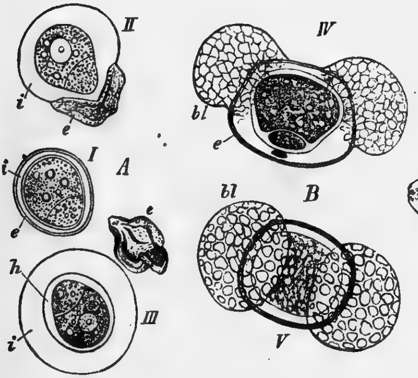


FIG. 285.

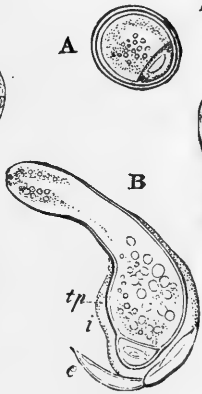


FIG. 286.

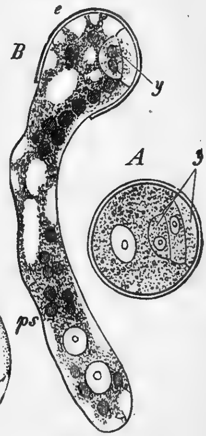


FIG. 287.

Fig. 285.—*A*, pollen grains of *Biota orientalis* before their escape from the pollen sac; *I.*, fresh; *II.* and *III.*, after lying in water, the extine, *e*, having been stripped off by the swelling of the intine, *i*; the protoplasmic contents are seen to consist of two cells, a large nucleated one, and a smaller one. *B*, pollen grains of *Pinus pinaster*, before their escape from the pollen sac; *e*, extine, with its vesicular protrusions, *bl*; *IV.*, side view; *V.*, dorsal view—the protoplasmic contents are divided similarly to those in *A*. Magnified.—After Sachs.

Fig. 286.—*A*, a pollen grain of *Cupressus sempervirens*, showing the envelopes (extine and intine), and the rudimentary prothallium as a small cell cut off from the cell contents. *B*, a germinating pollen grain; *e*, the fragments of the ruptured and exfoliated extine; *i*, intine; *tp*, the base of the pollen tube. × 400.—After Schacht.

Fig. 287.—Pollen grains of *Ceratozamia longifolia*. *A*, before germination; *y*, a three-celled body, the rudimentary prothallium. *B*, a germinating pollen grain; *e*, the ruptured extine; *ps*, the pollen tube; *y*, rudimentary prothallium. Magnified. —After Jurányi.

508.—The pollen grains, like the male flowers themselves, are essentially alike, although differing considerably in external appearance. The vesicular protrusions of the extine (*bl*, Figs. 285, *B*, and 281, *B*), which are common in certain genera of the order *Coniferæ*, at first sight hide the close similarity which exists between the pollen grains in many cases. (Compare *A, I.*, in Fig. 285, with *B, IV.* of the

same figure.) In all cases, unless possibly the Gnetaceæ furnish some exceptions, the pollen grains become more than one-celled before the formation of the pollen tube (Figs. 281–5–6–7). When the pollen grains germinate—*i.e.*, send out their tubes—they always swell up and burst the extine (which slips off in the Coniferæ), and the intine is then prolonged into a tube, which is continuous with the cavity of the grain, and into which the protoplasmic contents pass (Figs. 286 and 287). The small cells take no active part in the formation of the tube, and from their similarity, both in structure and function, to the small cells in the germinating microspores of the *Selaginellæ*, there can be no doubt that they are to be regarded as constituting a rudimentary prothallium.

509.—The female flower is in most cases a similar elongated axis, upon which are arranged spirally a considerable number of phyllomes, each bearing two or more naked ovules. Thus in *Abies pectinata* the female flower is the young cone, which consists of an axis (*sp*, Fig. 288, *B*) bearing narrow bracts (*c*), which, in turn, develop thick scales (*s*, *s*) upon their upper surface. The scales are at first quite small (as in *A*), and it is only as the cone becomes older that they grow larger. Each scale bears on its inner face two inverted ovules (*sk*, Fig. 288, *A*).

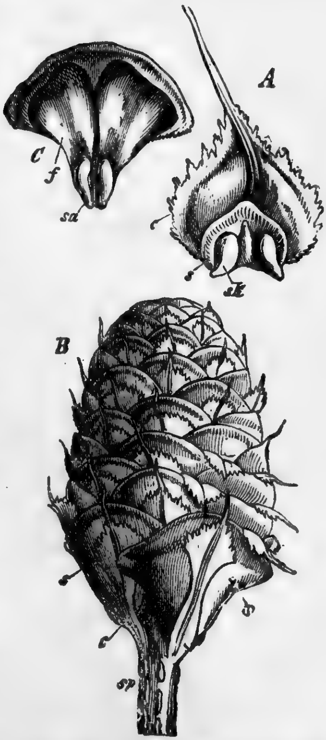


Fig. 288.—*A*, a bract, *c*, detached from the axis of a young cone of *Abies pectinata*, with the scale, *s*, bearing the ovules, *sk* (enlarged). *B*, upper part of a mature cone; *sp*, axis; *c*, bracts; *s*, largely developed scales, bearing the seeds on the upper surface (reduced). *C*, ripe scale, with two winged seeds; *sa*, seed; *f*, wing (reduced).—After Schacht.

In *Pinus sylvestris* the structure is essentially the same as

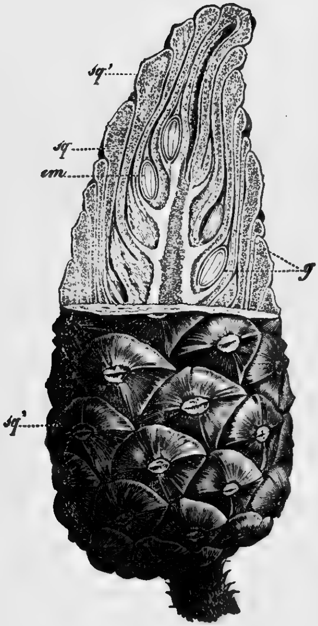


FIG. 290.

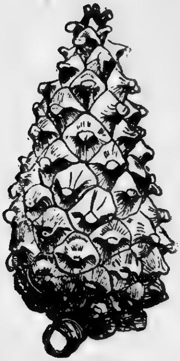


FIG. 289.

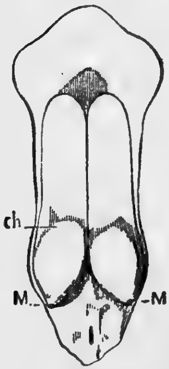


FIG. 291.

FIG. 292.

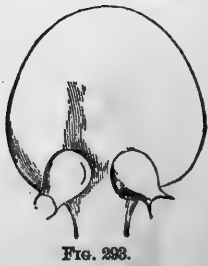


FIG. 293.

Fig. 289.—A ripe cone (female flower) of *Pinus sylvestris*.

Fig. 290.—Partial section of a cone. *sq*, *sq*', the scales; *g*, the seeds; *em*, the embryo in the seed.

Fig. 291.—A detached scale of a ripe cone, seen from above, bearing two seeds. *M*, micropyle; *ch*, chalaza.

Fig. 292.—A detached scale of a young cone, seen from the back, showing the triangular bract. Magnified.

Fig. 293.—The same as Fig. 291, seen from the front, showing the two ovules. Magnified.

in the foregoing. The bract is smaller, however, and the scale attached to it soon becomes very large, thick, and woody (Figs. 289, 290, and 291). The bract and scale in this case have nearly the same relative proportions when young as they have in the mature cone of *Abies pectinata.* (Compare Fig. 288 with Figs. 292–3.)

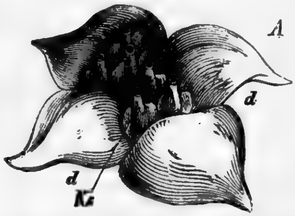


Fig. 294.—Female flower of *Callitris quadrivalvis. d, d,* decussating carpellary leaves; *Ks,* six ovules. Magnified.—After Sachs.

In other cases, as in *Callitris quadrivalvis*, the axis is short, and the phyllomes (*d*, Fig. 294) which bear the ovules are only four in number (Fig. 294, *Ks*, the ovules). In *Taxus baccata* the flower is still more simple. It appears in the axil of a foliage leaf, and is a scaly axis, resembling a small cone (*C*, Fig. 284). The lower scales do not, however, bear ovules, and at the top of the axis is a single naked ovule (*D* and *E*, Fig. 284). This simplicity is carried a step further in *Ginkgo*, where the female flowers are merely naked axes, which bear no bracts or scales, and produce but two ovules at their summits (Fig. 295, *sk*).*

Fig. 295.—A shoot of *Ginkgo biloba. sk*. ovules in pairs at the ends of naked axes; above and on the right are shown fragments of two leaves, which are seen to be broad. Nat. size.—After Sachs.

The female flower of *Cycas revoluta* is a rosette of phyllomes, which bear some resemblance to foliage leaves, being, however, smaller, brownish, and hairy. Along the lower parts of their margins they produce a number of spherical naked ovules (*sk*,

* The morphology of the flowers of *Ginkgo*, as here given, is by no means satisfactory. Instead of the ovules being borne upon naked axes, it is probable that they are in reality upon foliar organs—*i.e.*, either modified leaves, somewhat as in *Cycas*, or upon elongated homo-

Fig. 296). These structures, which may be called carpellary leaves, show their relationship to ordinary foliage leaves

Fig. 296.—A pinnate, open carpellary leaf of *Cycas revoluta* (reduced one half). *f*, unaltered pinnæ; *sk*, young ovules replacing the lower pinnæ; *sk′*, fully developed ovule.—After Sachs.

in having pinnæ toward their summits (*f*, Fig. 296).

The examples given will illustrate the general structure of

---

logues of the "scales" of *Abies*. Either interpretation would necessitate a considerable change in the systematic arrangement of *Taxineæ*.

the female flower of the Gymnosperms. The only considerable departure from the plan of the flower, as here given, is found in the order *Gnetaceæ*, which will be described further on.

510.—The ovule is at first a minute protuberance of

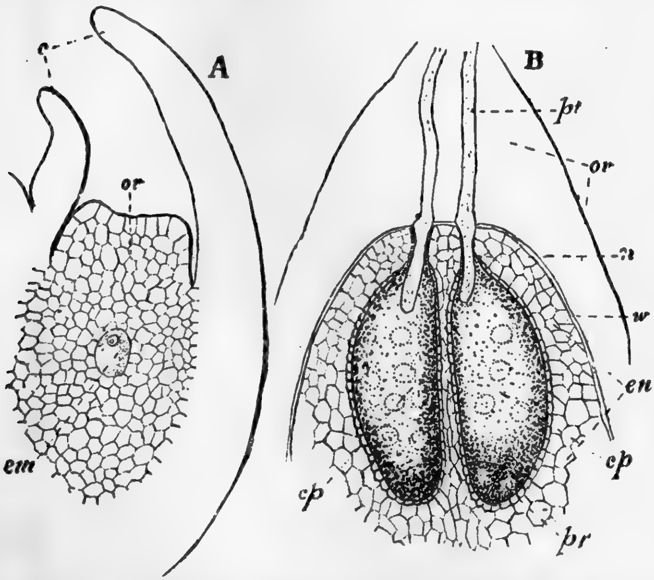


Fig. 297.—*A*, longitudinal section of an ovule of *Pinus Larico*, taken from a cone just opened ; *c*, the coat of the ovule, in section ; *ov*, the body or "nucleus" of the ovule ; this includes all the figure which is filled out, showing the cells ; *em*, the young embryo sac. *B*, a similar section of the ovule of *Abies pectinata*, after the entrance of the pollen tubes, *pt*, into the corpuscula, *cp*, *cp* ; *ov*, the body or "nucleus" of the ovule—the upper portion is cut away (the cells composing its tissue are not shown); *w*, the wall of the embryo sac; *en*, endosperm in the enlarged embryo sac ; *cp*, *cp*, two corpuscula ; *n*, the neck of one of the corpuscula ; *pr*, the first cells of the pro-embryo. *A* × 150 ; *B* × 30.—*A* after Hofmeister ; *B* after Strasburger.

small-celled tissue ; a little later a ring grows out from its base, and rises as a sheath (the *integument* or *coat*), which finally more or less completely closes it in ; in a few cases a second integument forms outside of the first one. At a certain stage of its growth one of the interior cells of the ovule grows larger than the others, and becomes the embryo sac (*em*, Fig. 297, *A*) ; in it there arise numbers of free cells,

which multiply by fission, and eventually unite into a continuous tissue (in reality a false tissue), the endosperm (*en*, Fig. 297, *B*). In this mass of endosperm cells several near the micropylar end grow larger than the surrounding ones, and become filled with granular protoplasm. These are the *corpuscula* of Brown, the *archegonia* of Sachs, or the *secondary embryo sacs* of Henfrey (*cp*, *cp*, Fig. 297, *B*). In some cases they are placed singly at short distances from each other, while in others they are clustered together (1 and 2, Fig. 298). Each corpusculum is at first a single cell, but when fully developed it consists of an elongated cell, the germ-cell proper, and, in many cases at least, one or more neck-cells, the whole sunken deeply into the substance of the endosperm. The neck is formed by the cutting off of a portion of the original cell of the corpusculum; in some cases it remains single, while in others it divides so as to form a vertical row, and in others a four- or even eight-celled transverse plane (see Fig. 298, 1); the latter arrangement has been termed a rosette.

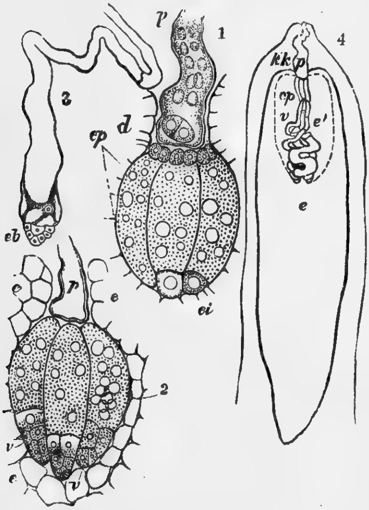


Fig. 298.—1. Three corpuscula, *cp*, of *Juniperus communis*, close together, and seen in a longitudinal section of the ovule; *ei*, the first suspensor cells of two fertilized corpuscula—at the upper end of the corpuscula are shown the neck cells; *p*, the lower end of the pollen tube. 2. A similar section taken a little later; *v*, *v*, the suspensors, or pro-embryos; *e*, *e*, *e*, cells of the endosperm. 3. Lower end of suspensor, with embryo, *eb*, beginning to develop. 4. Longitudinal section of the body or "nucleus," *kk*, of the ovule, shown in outline; *e*, endosperm in enlarged embryo sac; *e'*, portion of endosperm broken up; *cp*, three corpuscula, from the lower ends of which the suspensors, *v*, grow; *p*, pollen tube. 1 and 2 × 200; 3 × 100; 4 × 50.—After Hofmeister.

511.—If we now review the structure of the ovule its homologies can be readily made out. The ovule itself plainly corresponds to the macrosporangium of the higher Pteridophytes, and the embryo sac is to be regarded as the homo-

logue of a macrospore, which here is not freed from the parent plant. The endosperm clearly bears the same relation to the embryo sac as the prothallium of *Isoetes* does to the macrospore; and the corpuscula are slightly modified archegonia. In some corpuscula the resemblance to archegonia is very marked, the germ-cell below being surmounted by a short neck; Strasburger has even discovered a rudimentary axial-cell, thus completing the correspondence of these organs to those of the higher Pteridophytes.

512.—Fertilization is effected by means of the pollen, which comes in contact with the apex of the ovule. It is transported from the male flowers mostly by the wind, which accounts for the immense quantity produced. When the ovule has reached the proper stage the micropyle is filled with a fluid, which, drying, carries the adherent pollen grains into contact with the apex of the ovule body, where they germinate and form pollen tubes; the latter penetrate the soft tissue of the ovule and eventually reach the corpuscula (Fig. 299). In those cases where the corpuscula are separated from one another each pollen tube comes in contact with only one corpusculum (Figs. 297, *B*, and 299); but when the corpuscula are close together a single pollen tube may come in contact with all of them (Fig. 298, 1 and 2). The union of the protoplasm of the pollen tube with that of the germ-cell appears to take place by diffusion through the wall of the former, as no openings in it have been discovered. After fertilization the protoplasm in the germ-cell becomes more turbid and granular, and soon at the base a transverse partition is formed, cutting off a cell, which is the rudiment

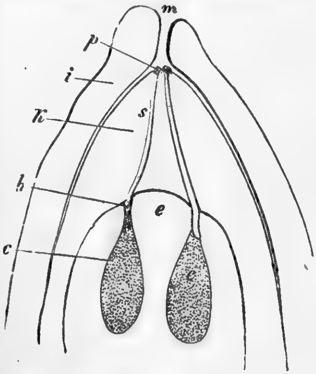


Fig. 299.—Diagrammatic section of an ovule of *Pinus*, showing fertilization. *i*, integument or coat of the ovule; *m*, the micropyle; *k*, the body or "nucleus" of the ovule; *e*, the embryo sac, filled with endosperm; *c*, *c*, two corpuscula shown filled with protoplasm; *h*, the neck cell of one corpusculum; *p*, two pollen grains applied to the apex of the ovule body, into which they have sent two pollen tubes, *s*, *s*.—After Prantl.

of the suspensor. By the growth and fission of this first cell an elongated tortuous filament—the suspensor—is at length formed, which develops at its lower extremity a rudimentary embryo (*eb*, Fig. 298, 3). Sometimes each suspensor splits into several parallel ones, each of which forms a rudimentary embryo, but in such cases it rarely happens that more than one continues to grow. While the embryo is growing the ovule increases greatly in size, and its coat becomes hardened or otherwise modified. Internally, the endosperm in the embryo sac grows still more rapidly, and finally entirely replaces the other tissues of the ovule. The endosperm-cells at this stage are filled with nutrient materials for the support of the embryo.

513.—The stem of the embryo develops upon the lower end of the suspensor as a very short cylindrical mass; the end opposite to the suspensor is a growing point (*punctum vegetationis*), and this produces two or more cotyledons as lateral members; lastly, upon the end of the axis next to, and under, the suspensor a rudimentary root forms, covered with a few-celled root-cap. The fully formed embryo has thus, (1) an axis (called also the hypocotyledonary stem, caulicle, and erroneously the radicle); (2) the cotyledons; (3) a growing point above the whorl of cotyledons (called also the plumule); (4) a rudimentary root, which is the true radicle, and to which alone the term should be applied.

514.—When the ovule and its contained embryo reach the stage last described above they constitute the *Seed.* The growth of the embryo is suspended, and the tissues which maintained organic connection between the ovule and the parent plant are absorbed, thus setting the seed free. Under proper conditions the suspension of the growth of the embryo may be prolonged for some years without the loss of its power of resuming it again; this latter, or the germination of the seed, takes place whenever the necessary amounts of heat and moisture are present. The first stage in germination is the swelling of the endosperm, which ruptures the hardened integument (testa); this is followed by the rapid elongation of the axis (caulicle) of the embryo, by which the growing root is pushed out (Fig. 300, *II.*); the latter forms

the first root of the new plant, and eventually gives rise to its whole root system. The cotyledons having thus far been in contact with the endosperm, which furnished them with nourishment, now elongate and push out their bases, and in some cases eventually withdraw themselves entirely from the seed coat (Fig. 300, *III.*). The apex of the axis (plumule) begins a rapid growth, which gives rise to a leafy stem resembling that of the parent plant, although usually somewhat simpler.

515.—The tissues of the Gymnosperms are individually but little higher than those of the Pteridophytes, but in the mode of their aggregation they present great and important differences, in this latter respect bearing a close resemblance to the tissues of the Dicotyledons among the Angiosperms. The three tissue sys-

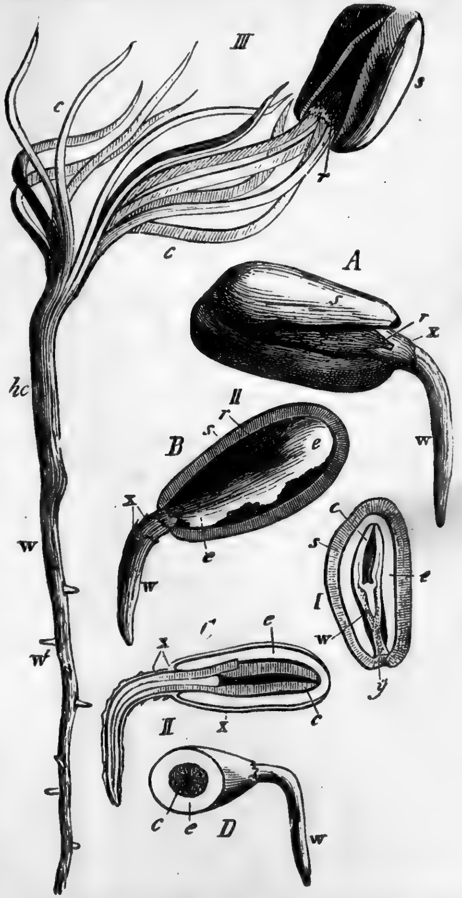


Fig. 300.—Seeds of *Pinus Pinea* in different stages of germination. *I.*, ripe seed in longitudinal section; *s*, the seed coat; *e*, endosperm; *w*, the hypocotyledonary axis of embryo; *c*, cotyledons; ÿ, the micropylar end of the seed, with the root of the embryo directed towards it. *II.*, *II.*, four views of the beginning of germination; *A*, external view; *B*, with half of the seed coat removed; *C*, in longitudinal section; *D*, in transverse section; *s*, seed coat; *r*, red membrane lining the seed coat; *e*, endosperm; *c*, cotyledons; *w*, root; *x*, ruptured embryo sac. *III.*, germination complete, the cotyledons, *c*, unfolding, and the hypoctyledonary stem, *hc*, elongating; *w*, the main root, developing lateral roots, *w'*.—After Sachs.

tems are well defined, and include most of the tissues described in Chapter VI. (page 69 et seq.).

The epidermal system consists of one or more layers of epidermal cells, which are frequently much thickened;

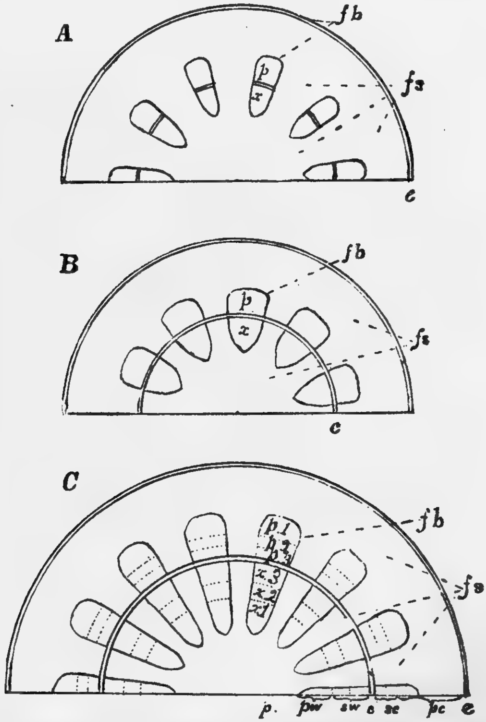


Fig. 301.—Diagrammatic cross-sections of the stem of Gymnosperms. *A*, young stem with the fibro-vascular bundles, *fb*, widely separated; *p*, the phloëm; *x*, the xylem; *fs*, tissues of the fundamental system; *e*, epidermis. *B*, a similar section of an older stem, the cambium layer, *c*, extended through the fundamental system from bundle to bundle. *C*, section of a three-year-old stem, showing the manner of increase in the xylem and phloëm; *pc*, primary cortex (phloëm); *sc*, secondary cortex (phloëm); *c*, cambium layer; *sw*, secondary wood (xylem); *pw*, primary wood (xylem); *p*, pith; *p*1, *p*2, *p*3, *x*1, *x*2, *x*3, corresponding phloëm and xylem portions of each year's growth of the bundle.

stomata are common, and in general, are quite regularly disposed in lines; the outer surface is occasionally covered with well-developed trichomes; in general, however, they present themselves as rough points, which give a harshness to the

surface. In many cases oil or resin receptacles occur in, or immediately beneath, the epidermis.

516.—The fibro-vascular bundles are for the most part of the collateral form, and in the young stem they are arranged so as to form an inner xylem cylinder ensheathed by a phloëm cylinder (Fig. 301). The xylem of these first-formed bundles is composed of an inner mass of annular and spiral vessels, which gradually pass outwardly into tracheïdes. The phloëm is mostly composed of an outer mass of bast

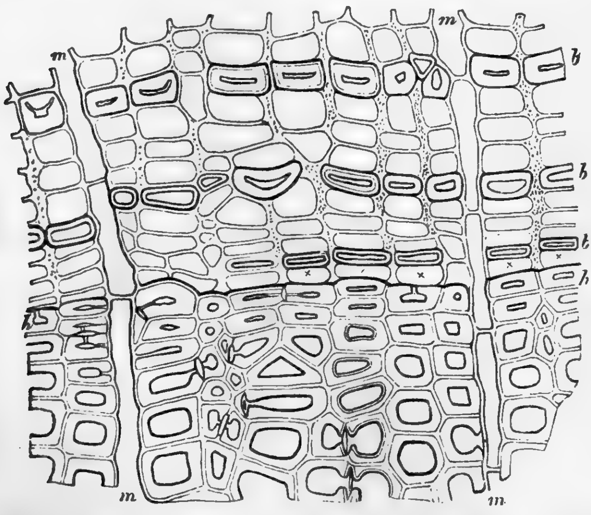


Fig. 301*a*.—Cross-section through the new wood (*h–h*), cambium (×–×), and bark (*b–b*) of the stem of *Juniperus communis*, made at the end of September. *m*, *m*, medullary rays. In the bark are shown the layers of bast fibres, *b*, *b*, *b*. Magnified.—After De Bary.

fibres, which is bordered internally by a mass of sieve tissue (latticed or cambiform cells) and parenchyma. Between the xylem and the phloëm a layer of cells always remains as a meristem tissue; this constitutes the cambium layer of the bundles (*c*, Fig. 301, *B*., and ×–×, Fig. 301*a*).

517.—The increase in the diameter of the stem takes place by the multiplication of cells in the cambium layer; the cambium cells undergo longitudinal fission by the formation of partitions at right angles to the radii; these new cells

are developed on the one hand into tracheïdes, which compose the secondary wood, and on the other into parenchyma and fibrous tissue, composing the secondary cortex (*sw* and *sc*, Fig. 301, *C*). There always remains a layer of meristem tissue between the secondary wood and cortex thus formed, so that the next year an additional increase is made again in exactly the same manner. Thus it happens that the new growth takes place between the xylem and phloëm portions last formed, and that the corresponding xylem and phloëm parts of any year's growth come at last to be separated by the similar parts of all the subsequent years' growths (*fb*, Fig. 301, *C*).

The tracheïdes are much elongated, with somewhat tapering ends; their walls are thickened, and are more or less copiously supplied with bordered pits. (See Fig. 15, p. 25.)

518.—The fundamental system of tissues in the stem becomes divided into two portions by the development of the fibro-vascular cylinder described above. The inner portion, the pith, which occupies the axis of the stem, is composed of parenchyma, which soon loses its vitality, and persists as a mass of thin-walled and generally empty cells. The outer portion, the primary cortex, consists of parenchyma, which is usually chlorophyll-bearing, and a greater or less amount of sclerenchyma or collenchyma. There is frequently a considerable development of cork in the primary cortex, and not rarely the whole of the primary cortex undergoes a corky degeneration. Between the fibro-vascular bundles there are broader or narrower plates of tissue, composing the so-called medullary rays, which in the young stems are parenchymatous, but in older ones they are sclerenchymatous (Fig. 301*a*, *m*, *m*). In that portion of each medullary ray lying between the cambium layers of two contiguous fibro-vascular bundles there is a layer of meristem tissue, the cambium of the medullary rays, or the inter-fascicular cambium. As this is continuous with the cambium of the bundles, there is thus formed a cylinder of cambium, separating not only the fibro-vascular, but also the fundamental portions of the stem, into two parts (*B*, Fig. 301). By the formation of new cells by fission in the inter-fascicular cam-

bium at the time of activity in the cambium of the fibro-vascular bundles, there is an annual addition made to the fundamental tissues of the stem corresponding to the addition made in the fibro-vascular bundles.

519.—By this internal increase of tissues in the stem the epidermis is at length ruptured, and the primary cortex becomes exposed, and eventually broken up and destroyed. The phloëm portions of the fibro-vascular bundles, and the subsequent external additions to the fundamental tissues made by the inter-fascicular cambium, constitute what is called the *Bark* of the stem. There are usually in it corky developments, which often very considerably change the character and alter the relations of its parts. The parenchyma frequently becomes somewhat sclerenchymatous, while in other cases it undergoes a peculiar degeneration.

520.—Most Gymnosperms have intercellular canals in their stems, either in the fibro-vascular or the fundamental portions; these contain a turpentine in which is dissolved a resin.*

521.—There are three quite well-marked orders of Gymnosperms, which may be separated as follows:

1. **Cycadeæ,** the Cycads. Stem simple, or rarely branched, not resinous; pith large; leaves large, pinnately compound, crowded upon the stem.

2. **Coniferæ,** the Conifers. Stem branched, usually resin-

---

* The distribution of these canals has been made out by Van Tieghem (*Ann. des Sci. Nat.*, 1872) to be as follows for the principal genera of *Coniferæ:*

1. No canals in root or stem—*Taxus.*
2. Canals in the stem only.
   (*a*) In the cortical parenchyma—*Taxodium, Podocarpus, Torreya, Tsuga,* etc.
   (*b*) In the pith also—*Ginkgo.*
3. Canals in both stem and root.
In the cortical parenchyma of the stem—*Cedrus, Abies,* etc.
   (*a*) In the xylem of the fibro-vascular bundles of root and stem—*Pinus, Larix, Picea, Pseudolarix.*
   (*b*) In the phloëm of the fibro-vascular bundles of root and stem—*Thuya, Cupressus, Biota, Araucaria,* etc.

ous; pith slender; leaves small, simple, mostly crowded upon the stem, sometimes scattered.

3. Gnetaceæ, the Joint-Firs. Stem branched, not resinous; pith slender; leaves small, opposite, upon elongated internodes, or large and only two on a short, thick stem.

Order Cycadeæ.—The Cycads are large or small trees, with much the general appearance of the palms and tree-ferns. They are of slow growth and are long-lived; the stem elongates by a slowly unfolding terminal bud, which gives rise to a crown of widely-spreading pinnate leaves, which are constantly renewed above as they die and fall away below.

Nine genera (*Cycas, Encephalartos, Macrozamia, Zamia, Ceratozamia,* etc.), and from fifty to sixty species. are known; they are all tropical or sub-tropical, and are about equally distributed in both the Eastern and Western continents. Three species occur within the United States (in Florida), viz., *Zamia integrifolia, Z. pumila, Z. Floridana.*

Many species contain considerable quantities of starch in their thick stems; from this a kind of sago is made. In some cases the seeds also are nutritious.

Order Coniferæ.—The Conifers are for the most part trees of a considerable size, with branching, spreading, or spiry tops. They are generally of rapid growth, and in many cases attain a great height and diameter. In the greater number of species the leaves are persistent, and the trees, consequently, evergreen.

The order contains thirty-three genera and about three hundred species, which are distributed mainly in the cooler climates of the globe. Fifty or more species occur within the limits of the United States.

The disposition of the genera may be understood from the following arrangement, which is essentially that of Parlatore in De Candolle's "Prodromus":

Tribe I. Taxineæ.—Flowers diœcious or rarely monœcious; fruit fleshy; non-resinous trees or shrubs.

Gen. *Ginkgo* (*Salisburia*), *Phyllocladus, Podocarpus, Torreya, Taxus,* etc.

The seeds of *Ginkgo* are eaten in Japan as a dessert. Many species furnish valuable timber, which is generally very durable. The wood of the yew (*Taxus baccata*) of Europe and Asia is almost indestructible.

Species of *Podocarpus* in Java, Australia, and New Zealand attain a great height, and afford good timber; allied species in the West Indies and South America are equally valuable.

Ginkgo is now planted in this country as an ornamental tree.

Tribe II. Abietineæ.—Flowers monœcious or diœcious; fruit a woody cone (excepting in *Juniperus*). Resinous trees, a few shrubs.

Sub-Tribe I. Cupresseæ.—Scales of the cone four or more, decussately opposite, or three or four in a whorl, persistent. Leaves usually scale-like, persistent, opposite or whorled.

Gen. *Juniperus, Cupressus, Chamæcyparis, Thuya, Libocedrus, Callitris,* etc.

The fleshy cones (the so-called berries) of *Juniperus communis* are used in medicine, as are also the leaves of *J. Sabina;* from the former an oil is obtained by distillation.

The wood of most of the species is valuable.

From *Juniperus Virginiana* of North America and *J. Bermudiana* of the Bermudas, the wood is obtained for making lead pencils.

Cupressus sempervirens is the Cypress, a native of the Levant; its wood is nearly indestructible. *C. macrocarpa* is the beautiful "Monterey Cypress" of California.

Chamæcyparis sphæroidea, the White Cedar of the Eastern United States, is used in the manufacture of pails, tubs, etc. Several allied species from Japan are cultivated under the name of *Retinospora.*

Thuya occidentalis, the Arbor Vitæ of the Eastern United States, supplies enduring posts, etc.; its congener of California and Oregon (*T. gigantea*) is an immense tree 30 to 60 metres (100–200 ft.) high.

Libocedrus decurrens, nearly related to the last named, is another large Californian tree.

Sub-Tribe II. Taxodieæ. — Scales of the cone spirally arranged (whorled in one genus), persistent. Seeds three to nine upon each scale. Leaves usually linear, arranged spirally, or in two ranks.

Gen. *Taxodium, Sequoia, Sciadopytis,* etc. *Taxodium distichum,* the Bald Cypress of the Southern United States, is valuable for its durable timber. *S quoia gigantea,* the Giant Redwood, or Big Tree of California, grows only on the western slopes of the Sierra Nevada Mountains. It attains a height of more than 100 metres (300 ft.), and a diameter of 6–10 metres (20 to 30 ft.). Its wood is red in color, and very durable. *S. sempervirens,* the Redwood of the Coast Range Mountains, is a somewhat smaller tree; its durable timber is much used for making shingles, weather-boarding, fences, etc. *Sciadopytis verticillata* and *Cryptomeria Japonica,* large trees of China and Japan, furnish valuable timber. They are now considerably grown in the United States.

Sub-Tribe III. Pineæ.—Scales of the cone spirally arranged, usually persistent. Seeds two upon each scale. Leaves linear (or, in some cases, scale-like on the primary shoots), spirally arranged.

Gen. *Tsuga, Abies, Picea, Larix, Pinus,* etc. *Tsuga Canadensis,* the Hemlock-Spruce of the Eastern United States, and *T. Douglasii* (*Pseudotsuga Douglasii* of Carrière), the Douglas Spruce of Oregon and California, are valuable timber trees. The former attains a height of 30 metres (100 ft.), and the latter of nearly 100 metres (300 ft.). Both are valuable for making the frames of houses and ships.

The genus *Abies* contains the Balsam Fir, *A. balsamea,* of Eastern United States, the Silver Fir of Europe, *A. pectinata,* the Giant Silver Fir, *A. grandis,* of Oregon and California, besides many others. All furnish valuable timber, and from the first is obtained a fine turpentine known as Canada Balsam.

Picea excelsa, the Norway Spruce of Northern Europe, is a large tree 30 to 50 metres (100–150 ft.) high, from which white deal timber is obtained ; from its turpentine Burgundy pitch is made. *P. alba,* the White Spruce of Canada, and *P. Sitchensis* and *P. pungens* of the Western United States, are valuable for timber, and are planted for ornamental purposes.

Larix Americana, the Tamarack or American Larch of Eastern North America, and *L. Europæa,* the Larch of the mountains of Central Europe, are valuable timber trees ; from the latter Venice turpentine is obtained.

The genus *Pinus* contains many important trees ; they may be grouped as follows :

(*a*) Leaves in fives.

P. Strobus, the White Pine of Eastern North America ; this is our most valuable species, as it furnishes the greater part of the pine "lumber" used in the Northern States ; it often attains a height of 50–60 metres (160–200 ft.).

P. Lambertiana, the Sugar Pine of California, is like the preceding, but of greater size, being from 60 to 90 metres high (200–300 ft.).

(*b*) Leaves in threes.

P. au tralis, the Yellow Pine of the Southern United States, furnishes a durable timber, used for flooring, shipbuilding, etc. Its turpentine, which is obtained by cutting into the trees, yields spirits of turpentine by distillation ; the residue is rosin. Tar is obtained by slowly burning the wood in kilns ; and by evaporating the volatile matters from tar, pitch is produced.

P. ponderosa, the Yellow Pine of the Rocky Mountains and California, is similar to the former, but of greater size, being 30–100 metres high (100–300 ft.).

(*c*) Leaves in twos.

P. sylvestris, the "Scotch Fir," or "Scotch Pine," is a native of Northern Europe and Asia. Its timber is extensively used in England under the names of Dantzic Fir and Riga Fir, in the building of ships, docks, houses, etc.

P. laricio is a less valuable tree of Southern Europe ; it is known in this country as Austrian Pine, and, with the preceding, is commonly planted with us for ornamental purposes.

P. resinosa, the Red Pine of Canada, is a tall and slender tree, much used for making masts and spars.

(*d*) Leaves single.

P. monophyllos, the Nut Pine of the Utah-Arizona district, is pecu-

liar in its single leaves. Its seeds are large and constitute an important article of food for the Indians.

Sub-Tribe IV. Araucarieæ.—Scales of the cone spirally arranged, deciduous. Leaves flat or four-angled, often broad, sub-opposite, or spirally arranged.

Gen. *Dammara, Araucaria. Dammara australis* is the Kauri Pine of New Zealand, which attains a height of 60 metres (200 ft.), and is much used for making masts. From *D. alba* of the Malay Islands Dammar resin is obtained.

The genus *Araucaria* contains large pyramidal trees of singular beauty. *A. excelsa*, the Norfolk Island Pine of the South Pacific Ocean, is 45 to 60 metres high (150–200 ft.), with horizontal verticillate branches, forming a pyramidal head. The timber is valuable. This species and *A. imbricata* from Chili, and *A. Bidwilli*, of Australia, are now grown for ornamental purposes in California.

Order Gnetaceæ.—The Joint-firs are undershrubs, or small trees, with usually jointed rush-like stems, and opposite setaceous or oval leaves (the exceptional *Welwitschia* will be described below). The flowers differ from those of the other Gymnosperms in always having a perianth—*i.e.*, a floral envelope; in some cases this is single and bifid, while in others it is composed of two or more bract-like bodies (phyllomes). The stamens are single (in *Gnetum*), or six to eight united into a tube or column. The ovules are single in each flower, and are provided with one or two envelopes;* in the former case the single integument, and, in the latter, the inner one, is prolonged beyond the body of the ovule into a style-like process, which is occasionally expanded above into a stigma-like body.

The flowers are disposed in the axils of the opposite bracts of short lateral branches (aments or catkins), which spring from the axils of the leaves upon the main stems.

Three genera of Gnetaceæ have been described, viz.: (1) *Gnetum*, with from fourteen to eighteen species, mostly confined to the East Indian islands and the tropical portions of South America; (2) *Ephedra*, with about as many species, widely distributed in temperate and tropical regions (five species occur in the southwestern part of the United States); (3) *Welwitschia*, with but one South African species.

---

* In *Gnetum Gnemon* there are three envelopes surrounding the body of the ovule, but it is probable that the outer one is to be regarded as belonging to the perianth. Some botanists reject the idea that any of these are proper ovule integuments, and regard the inner one as a true ovary, and the outer one or two as belonging to the perianth or staminal whorl. This is the position taken by Parlatore in De Candolle's "Prodromus;" by Beccari, in "Nuovo Giornale Botanico Italiano," Jan., 1877 (*Della Organogenia*, etc., *del Gnetum Gnemon*); and by Dr. Gray, in "Bot. Text-Book," 6th ed., 1879, vol. 1, p. 269.

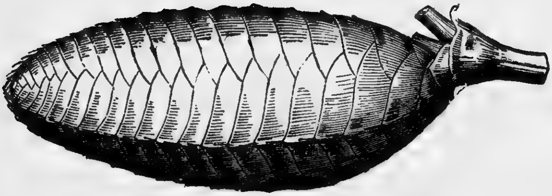


FIG. 303.

FIG. 302.

Fig. 302.—Adult fruiting plant of *Welwitschia mirabilis*, showing the large, persistent, strap-shaped cotyledons. $\frac{1}{25}$ natural size.—From Hooker's Monograph.

Fig. 303.—A ripe female cone. $\frac{3}{4}$ natural size.—From Hooker's Monograph.

The most remarkable member of the order is *Welwitschia mirabilis* (Fig. 302) discovered by Dr. Welwitsch in 1860, and described by Dr. Hooker in 1862.* It consists of a short, thick, woody stem rising 30 cm. (1 ft.) above the ground, and having a diameter of from 30 to 50 cm. (12 to 20 in.), and even attaining in some cases, according to the discoverer, a diameter of 1.4 metres (4⅔ ft.). From the lower portion of this stem a stout tap-root passes downward, branching more or less at its lower end. The top of the stem is nearly flat, there being usually a slight depression across its diameter. There are only two leaves attached to this curious stem, and from the study of the young plants it seems probable that they are the persistent cotyledons. They arise in two deep grooves in the circumference of the upper part of the stem, and as they continue to grow at their bases they eventually attain a great length, being nearly two metres long (6 ft.) in full grown plants. They are thick and leathery in texture, and their fibro-vascular bundles are all parallel and free from each other, running from the base of the leaf to its split and frayed apex. From the circumference of the stem, above and close to the bases of the leaves, spring stout branching peduncles, which bear clusters of scarlet cones (Figs. 302 and 303). These cones are composed of numerous opposite bracts arranged in four rows. In the axil of each bract there is a single flower, consisting in the male cones of a perianth of two pairs of decussating bracts enclosing a ring of partly united stamens; within these is a rudimentary, abortive ovule, whose single coat is curiously prolonged so as to resemble a pistil with style and expanded stigma. In the flowers of the female cones the perianth is a compressed, winged tube, lying within the broad scales. There are no rudiments of stamens; and in the centre of the perianth there is placed a single erect ovule with one elongated integument.

It will thus be seen that the cones of *Welwitschia*, while bearing some external resemblance to those of Coniferæ, are not homologous with them; in *Welwitschia* they are short, flower-bearing, bracted axes; in Coniferæ they are stamen-bearing or pistil-bearing axes, in other words, each cone is a multistaminate or multiovulate flower.

Fossil Gymnosperms.—Gymnosperms first appeared in the Devonian, in which they were represented by species of *Prototaxis*, *Cladoxylon* and *Schizoxylon*, doubtfully referred by Schimper† to the Coniferæ. True conifers were present in the Carboniferous, in the Permian they were abundant, and in the Tertiary exceedingly so. *Araucaria* was represented in the Jurassic by several species. *Pinus*, *Abies*, *Cedrus* and *Sequoia* originated during the Cretaceous period, and were repre-

* "On Welwitschia, a new Genus of Gnetaceæ," by J. D. Hooker, in "Transactions of the Linnean Society," Vol. XXIV.

† "Traité de Paléontologie Végétale," par W. Ph. Schimper, Paris, 1869–1874.

sented by many species during the Tertiary. It is interesting to note that the present small and restricted genus *Sequoia* was during Cretaceous and Tertiary times large and widely distributed throughout the northern hemisphere. In this country two Cretaceous species are recorded from Nebraska and Kansas, and eight species from the Tertiary of Colorado, Utah, Montana, and the region westward.

The Cycads originated in the Carboniferous, and increased in numbers to the Jurassic, in which twenty or more genera were richly represented in species. A Cretaceous species of *Pterophyllum* from Nebraska, and a tertiary *Zamiostrobus* from Colorado have been described.

Two species of *Ephedra* from the Tertiary of Europe are the only known fossil Gnetaceæ.

§ III. Class Angiospermæ.

522.—This class includes the great mass of the so-called flowering plants. The principal characters which set these off from the preceding small class of the Phanerogams (Gymnospermæ), are (1) the development of an ovary, and (2) the aggregation of the reproductive organs into a definite and distinct flower.

523.—The plants of this class have, in most cases, more or less elongated stems; these are solid at first, and in the great majority of cases they remain so. They usually bear ample leaves with a parallel (in the Monocotyledons), or netted venation (in the Dicotyledons). The disposition of the fibro-vascular bundles in the stem is either like that in the Gymnosperms (in most Dicotyledons), or they run through the fundamental tissues parallel to, but independent of, one another (in most Monocotyledons). In the former case, the stems of the perennial species increase in diameter, in the same way that they do in Gymnosperms, and there is here also a well-marked division into pith, wood and bark; in the latter case there is usually no increase in the diameter of the stem after it has elongated, and in the few cases of considerable increase it takes place by methods very different from that described in the preceding class.

Most Angiosperms are terrestrial and chlorophyll-bearing plants; there are, however, many aquatic and aerial species, and a considerable number of parasites. They range, also, in size and duration, from minute annuals, a millimetre in

extent, to enormous trees, 50 to 100 metres high, and often several or many centuries old.

524.—The flowers of the Angiosperms, while sometimes so reduced as to be quite simple, are in all cases much more complex than those of Gymnosperms. In most cases they are monoclinous (hermaphrodite), *i.e.*, the male and female sexual organs occur in the same flower; in such case each flower consists essentially of an axis bearing one or more pollen-producing organs (*anthers*, Fig. 304, *a*), and one or more ovule-containing organs (*ovaries*, Fig. 304, *F*). These are, when more than one, generally arranged upon the axis in one or more whorls; the staminal whorls normally arise below the ovaries. Besides these essential organs, there are usually secondary or accessory organs, such as the delicate, and frequently colored floral leaves (*petals* or *sepals*, *K* and *Ke*, Fig. 304), the honey glands, etc.

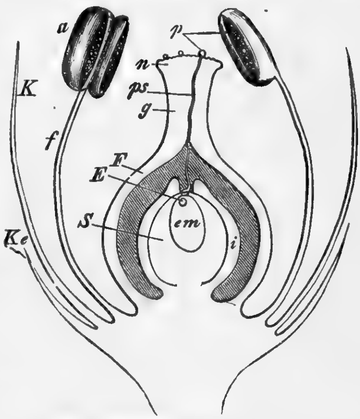


Fig. 304.—Diagrammatic section of an angiospermous flower. *Ke*, calyx; *K*, corolla; *f*, the filament, and *a* the anther of the stamen; *p*, pollen grains, some in the anther, others on the stigma; *F*, the ovary; *g*, the style, and *n* the stigma of the pistil—the ovary contains one ovule, which has a single coat, *i*, enclosing the ovule body, *S*; *em*, the embryo sac; *E*, germ cell or germinal vesicle; *ps*, a pollen-tube penetrating the style, and reaching the germ-cell through the micropyle of the ovule.—After Prantl.

525.—The axis of the flower (the *Torus* or *Receptacle*), usually remains very short, so that the different organs of the flower are closely approximated, and thus distinctly set off from the other parts of the plant. The axis is, moreover, but very rarely prolonged beyond the flower, all growth ceasing in it when the floral organs are developed. In most cases the receptacle is conical or hemispherical in shape; in other cases it develops into various shapes, the principal ones of which will be noticed hereafter.

526.—The lower portion of the flower axis generally bears one or more whorls of modified leaves (phyllomes), which

constitute the floral envelopes, or, technically, the perianth. Frequently there is a strong difference between the outer and inner whorls, and in such cases the former is distinguished as the calyx, and the latter as the corolla.

527.—The whorl of stamens (technically the *Andrœcium*) develops above the upper whorl of the perianth. Each stamen generally consists of a slender, thread-like stalk (filament), bearing upon its upper extremity from one to four pollen-sacs; this pollen-containing portion, whether one or more celled, is known as the anther. In its development the stamen at first bears a close resemblance to a rudimentary leaf, both in structure and position, and there can be no doubt that it is a phyllome, modified into a pollen-producing organ. Whether the anther is to be regarded as an outgrowth of the phyllome, or as its modified upper portion, is doubtful; analogy would indicate the probability of the former view. There can be but little doubt that the pollen-sacs are to be considered homologous with the microsporangia of the higher Pteridophytes, and the latter are clearly outgrowths (trichomes ?) upon phyllomes.

528.—The pollen-grains are developed here as in Gymnosperms. from pollen mother-cells; the latter are differentiated parenchyma cells, lying in or near the axis of the pollen-sacs. Each mother-cell undergoes two divisions (by fission), producing four parts, which become as many pollen-grains. The mature pollen-grain is a single cell, and consists of a mass of protoplasm mixed with oil-drops, starch granules, etc., surrounded by two investing membranes, an outer hard and firm one (the *extine*), and an inner thin and delicate one (the *intine*). In the germination of the pollen-grains, they always remain single cells, there being no formation of internal cells (rudimentary prothallium) as in the Gymnosperms. The development of the pollen-tube takes place as in Gymnosperms, by a prolongation and growth of the intine, but here the extine is not slipped off in the process, but only pierced in certain thin areas of its surface. Usually but one tube issues from each pollen-grain, but in some cases—*e.g.*, *Œnothera*—two or more are sometimes found.

529.—The female reproductive organs (individually the

pistils, and collectively the *Gynœcium*) normally develop upon the uppermost portion of the flower-axis, and within the whorl of stamens. They consist of one or more infolded, ovuliferous phyllomes (*carpophylla*) whose margins are united so as to form separate, or more or less united cavities (ovaries). The apical portions of the carpophylla are usually extended, terminating in a mass of loose parenchymatous tissue, the stigma. The ovules arise as outgrowths (trichomes, in the broader sense of the term) upon some portion of the interior surface of the ovary; they most frequently develop upon the margins of the carpophylla, although they are by no means confined to them. In some cases there is but a single ovule in each ovary, in others they range from a few to several hundred. In many cases, especially when the ovules are numerous, the ovuliferous portion of the ovary is developed into a thickened mass of tissues, the *placenta*, which projects more or less into the ovary cavity.

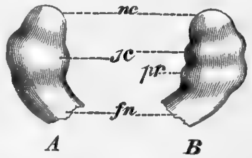


Fig. 305.—Very young ovules of *Eschscholtzia Californica*, showing successive stages of development. *nc*, the body or nucleus of each ovule; *fn*, the ovule stalk or funiculus—the ovule *A* is the younger of the two; the inner coat (the secundine) is just beginning to develop as a ring, *sc*; in *B* there are two rings, the upper being the rudimentary secundine, the lower the primine. × 140.—After Duchartre.

530.—Each ovule is at first a homogeneous mass of parenchymatous tissue, constituting the body (or so-called nucleus) of the ovule; a little later a circular ridge arises upon the ovule body; this grows upward, and forms an integument; a second integument generally forms in exactly the same way outside of the first (Fig. 305, *A* and *B*). From their position when fully formed, these coats have received the names *primine* and *secundine*, the former being applied to the outer, the latter to the inner.* The coats never completely enclose the body of the ovule, there always remaining a small opening (the micropyle) over its apex (*m*, Fig. 306,

* These terms were so applied by Mirbel, who was not acquainted with the order of development of the coats. Schleiden applied them in exactly the opposite way, which has led to some confusion. Mirbel's use of the terms, although not as good as Schleiden's, is the prevailing one.

A). In their development most ovules, although straight (Fig. 306, *A*) at first, become afterward more or less curved upon themselves (Fig. 306, *B* and *C*).

The development of the embryo sac takes place in a much simpler way in Angiosperms than in Gymnosperms.* An axial cell enlarges greatly, becoming thus the young embryo-sac (Fig. 306, *em*). In preparation for fertilization, it divides into a row of several (3–6) cells, the uppermost of which forms four nuclei, one of which becomes the germ-cell. By the absorption of the cell wall, the upper cell fuses with the second (which may or may not contain four nuclei), forming a common cavity containing many nuclei or young

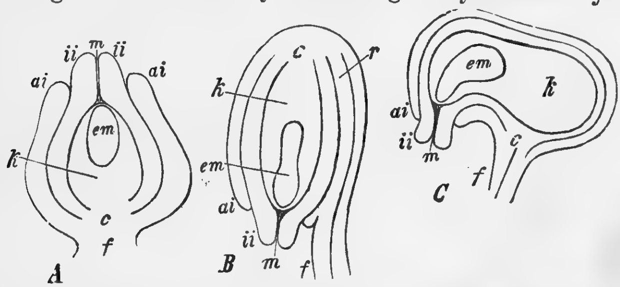


Fig. 306.—Diagrammatic longitudinal sections of ovules. *A*, the straight ovule (orthotropous); *k*, the body of the ovule, with its embryo sac, *em*; *ai*, the outer ovule coat (primine); *ii*, the inner coat (secundine); *m*, the micropyle; *c*, the base of the ovule, where the coats arise, called also the chalaza; *f*, the ovule stalk or funiculus. *B*, an inverted ovule (anatropous); the long funiculus, *f*, has fused with the primine of one side of the ovule and formed the raphé, *r*. *C*, a bent ovule (campylotropous).—After Prantl.

cells, several of which, including the Germ-Cell, remain at the top, the others (Antipodal Cells) occupying the lower part. No endosperm is to be seen at this stage.†

The fertilization of the germ-cell involves two operations, viz., Pollination—*i.e.*, the deposition of the pollen upon the stigma, and Fertilization proper.

* See "Nouvelles Recherches sur le développement du sac embryonnaire des Phanérogames angiospermes," by Julien Vesque, in *Annales des Sciences Naturelles*, 1879.

† The endosperm, which here forms *after* fertilization of the germ-cell, may be regarded as a belated prothallium. It is here no longer necessary for the prothallium to precede the formation of the germ-cell; there is consequently a considerable retardation in its development.

531. Pollination.—As the pollen-grains are entirely wanting in means of locomotion, they are dependent for transportation to the stigma, upon (1) the wind (*anemophilous* flowers) ; (2) certain contrivances, by means of which insects (or rarely birds) are made to carry the pollen from anther to stigma (*entomophilous* flowers) ; (3) the favorable position of the anthers and stigmas, bringing the pollen in the opening anther into contact with the stigmatic surface (*autogamous* flowers). The grasses and sedges, and the oaks, beeches, chestnuts, walnuts, birches, and their allies, and a few others, have anemophilous flowers. In these the pollen is produced in great abundance, and the flowers are small, uncolored, and destitute of nectar (honey). An immense number of plants have entomophilous flowers ; these are, as a rule, large, colored, and provided with nectar-secreting glands ; the nectar acts as a bait, and the showiness as a guide to honey-loving insects, which, by various structural contrivances in the flowers, are made to come successively in contact with the anthers of one flower and the stigmas of the next, in the first dusting their bodies with pollen, which in the second adheres to the stigmas. Autogamous flowers are much less numerous than either of the foregoing, and it is doubtful whether there are any species of plants all of whose flowers exhibit constant autogamy. There are a good many plants, however, which have two forms of flowers, viz., large, showy, nectar-bearing, entomophilous ones, and small, inconspicuous autogamous ones, generally with a rudimentary perianth. Flowers exhibiting this form of autogamy are said to be *cleistogamous*. Examples are to be met with in *Viola, Lithospermum, Impatiens,* etc. ; early in the season these have large flowers, which are entomophilous, but later only small cleistogamous ones appear, and in some species of *Viola* these are subterranean. Without doubt it frequently happens that the pollen of anemophilous and entomophilous flowers falls upon their stigmas, resulting in accidental autogamy, but too frequent a recurrence of this is guarded against by various structural devices.*

* Upon this interesting subject the student is referred to Mr. Darwin's works, " The Various Contrivances by which Orchids are Fertil-

532. Fertilization.—Fertilization takes place as follows: The pollen grain, resting upon the moist surface of the stigma, absorbs moisture and germinates, sending out a tube which penetrates the soft tissues of the stigma and style, finally reaching the cavity of the ovary, where it enters the micropyle of an ovule (Fig. 307, *A*). Here it comes in contact with the apex of the ovule body, through whose tissues it forces its way until it reaches the embryo sac; in some cases, however, the embryo sac has grown out through the apex of the ovule body into, and occasionally through the micropyle, thus meeting the pollen-tube. The transfer of the contents of the pollen-tube to the germ-cell has never been observed, but doubtless it takes place by diffusion through the pollen-tube and embryo sac. The first result of fertilization is the formation of a wall of cellulose around the germ-cell; the latter soon divides transversely one or more times, and thus gives rise to a row of cells, the suspensor, at the free extremity of which a rudimentary embryo is soon formed by the fission of cells in three planes (Fig. 307). Simultaneously with the foregoing

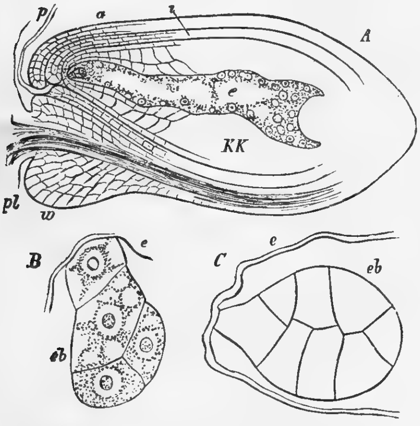


Fig. 307.—*A*, a longitudinal section of the anatropous ovule of *Viola tricolor*, after fertilization. *pl*, the placenta; *w*, the raphé, swollen at this point; *a*, the outer coat of the ovule; *i*, the inner; *p*, the pollen-tube which has entered the micropyle; *e*, embryo sac, with the very young embryo at the micropylar end, and numerous free endosperm cells at the other. *B*, apex of embryo sac, *e* (much more magnified); *eb*, very young embryo of two cells, supported by a two-celled suspensor. *C*, the same, further advanced. All the figures highly magnified.—After Sachs.

---

ized by Insects;" "The Effects of Cross and Self-Fertilization in the Vegetable Kingdom;" "The Different Forms of Flowers on Plants of the Same Species." Also Lubbock's "British Wild Flowers Considered in Relation to Insects," and Dr. Gray's "How Plants Behave."

development in the apical portion of the embryo sac, there is a corresponding one in the basal portion. The protoplasm gathers about certain points, and gradually condenses so as to form as many free and naked cells (Fig. 308). These soon become covered with cell-walls, and they then multiply rapidly by fission, until they fill up the embryo sac with a continuous tissue, the endosperm. (Consult p. 41, and Fig. 33, *A* and *B*.)

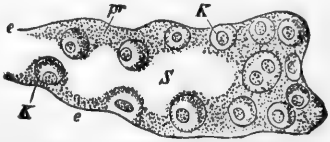


Fig. 308.—Posterior part of the embryo sac of *Viola tricolor*. *e*, its wall; *s*, cavity of the sac; *K*, *K*, young endosperm-cells which have formed in the protoplasm, *pr*. Highly magnified.—After Sachs.

533. The Development of the Embryo. (Figs. 309 and 310).—As stated above, one of the first results of the fertilization of the germ-cell is the formation of a row of from two to many cells, the suspensor or pro-embryo, the first or proximal cell of which is attached to the wall of the embryo sac close to the micropyle of the ovule; its distal, or free end, always grows toward the interior of the ovule, and

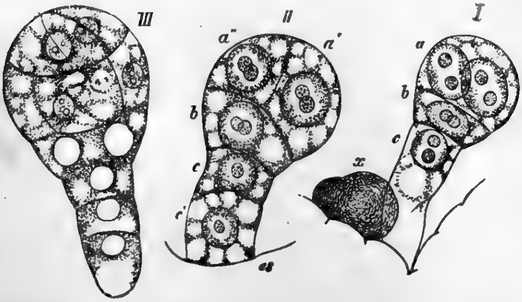


Fig. 309.—Embryos of *Allium cepa*. *I.*, very young stage; *c*, *b*, cells of suspensor; *a*, the single cell constituting the embryo; *x*, an unfertilized germ-cell. *II.*, an older stage, the embryo now two-celled, *es*, the wall of the embryo sac. *III.*, a still later stage. Much magnified.—After Sachs.

its last cell becomes transformed by successive fissions into a several-celled surface (*I.*, Fig. 310); by a continuation of the process a many-celled solid body is formed (*II.*, Fig. 310); partitions then arise in the cells parallel to the surface, and the external layer of daughter-cells thus formed constitutes the dermatogen or primary epidermis (*III.*, Fig. 310).

About this time there is in most cases a slight differentiation of the inner cells, foreshadowing the future tissue systems (*III.* and *IV.*, Fig. 310). A little later the cotyledons (one or two) appear; in the Monocotyledons, in one side of the thallus-like structure a depression forms, which becomes the *punctum vegetationis* of the embryo, and marks the limits of the stem and single cotyledon; in the Decotyledons two cotyledons grow out symmetrically from the distal end of the thallus-like structure, and the depression between them becomes the *punctum vegetationis* (*V.*, Fig. 310). The root is the last portion of the embryo formed; its cap (the pileorhiza) is developed from a layer of cells resulting from the successive fission of the penultimate cell of the suspensor, the hypophy-

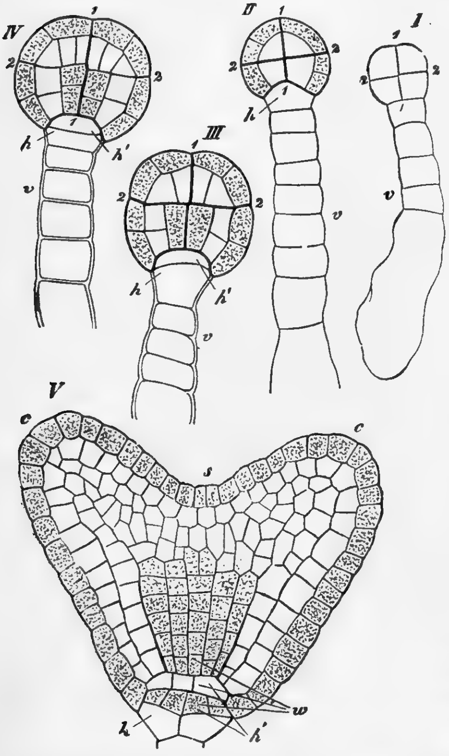


Fig. 310.—Development of the embryo of *Capsella Bursa-pastoris* (highly magnified). *I.*, *v.* suspensor, or pro-embryo of five cells, and terminated by a four-celled embryo; 1–1, the longitudinal wall which divided the first embryo-cell into two cells; 2–2, transverse wall which divided each cell of the two-celled embryo, making it four celled. *II.*, *v*, suspensor; *h*, the hypophysis, the basal part of the embryo formed by the division of the end cell of the suspensor; the shaded portion of the embryo is the dermatogen or primary epidermis. *III.*, embryo further advanced; the inner shaded cells constitute the plerome, between these and the dermatogen to the right and left are the cells of the periblem; the hypophysis is divided into two cells, *h*, *h'*. *IV.*, still older condition. *V.*, embryo considerably advanced; *c*, *c*, cotyledons; *s*, apex of stem; the dermatogen, periblem, and plerome shown as before; *w*, the rudimentary root, and root-cap formed from the cell *h'* of *III.* and *IV.*—After Hanstein.

sis (*h*, Fig. 310, *II.*, *III.*, *IV.*, *V.*). The growing points of both root and stem develop in all cases from masses of small cells, and never from single apical cells.

The development of the embryo may be studied by selecting the young ovaries of *Capsella Bursa-pastoris*, or *Lepidium intermedium*, and dissecting out the ovules in a solution of potassic hydrate, and afterwards transferring them to a solution of glycerine and water. Specimens prepared in this way show clearly the embryo sac with the contained suspensor and embryo when examined by means of a magnifying power of from one hundred and fifty to four hundred diameters. When they have been made too transparent by this treatment, their walls may be rendered more opaque by the addition of a dilute solution of alum. The young embryo may sometimes be separated from the ovule by a gentle pressure upon the top of the cover-glass.

534. The Endosperm.—During the early part of the development of the embryo, just described, the formation of endosperm cells within the embryo sac takes place with great rapidity; in most cases the growth of the endosperm is so great as to displace the greater part or even the whole of the surrounding tissues. The cells of the endosperm contain large quantities of nutrient matters, which are at first in solution, but which later may pass into a less soluble condition. The growing embryo is imbedded in the endosperm, and as the former increases in size, the latter is displaced and absorbed. In many cases the growth of the embryo is arrested before the endosperm is all absorbed—*e.g.*, in Ranunculaceæ, Violaceæ, Solanaceæ, Euphorbiaceæ, Palmaceæ, Liliaceæ, Gramineæ, etc.; in other cases the embryo continues to grow until it has entirely absorbed the endosperm—*e.g.*, Cruciferæ, Rosaceæ, Myrtaceæ, Compositæ, Salicaceæ, Cupuliferæ, Alismaceæ, etc.

535. The Perisperm.—It rarely occurs that the endosperm develops but slightly, and in such cases there is a considerable development of the tissues of the ovule surrounding the embryo sac, constituting the perisperm; in such cases nutrient matters are contained in the latter, which functionally replaces the endosperm. Examples of this structure occur in Nymphæaceæ, Piperaceæ, and Cannaceæ.

536.—During the growth of the embryo the ovule and ovary undergo considerable changes. The outer coat of the

ovule becomes hardened by the conversion of parenchyma into sclerenchyma, thus forming the testa ; in other cases it becomes more or less pulpy, as in *Magnolia, Pæonia,* etc. The outer coat is liable to be much modified in form also, being sometimes developed into thin wings, or a tuft or covering of hairs, as in *Bignonia, Asclepias, Gossypium,* etc. The inner coat usually undergoes little change, generally becoming thin and dry. The ovary in many cases becomes hard and dry—*e.g.*, in Cupuliferæ and Leguminosæ ; in others it is more or less pulpy, as in the Cherry, Plum, Blackberry, etc. Both ovule and ovary at maturity (now called *seed* and *pericarp* respectively, and the latter, with all its contained seeds, the *fruit*) spontaneously separate from their supporting parts, by the breaking away of the walls of certain layers of cells.

The development of the flower as a whole, or, as it is termed, the Organogeny of the flower, is an important and instructive subject of study. The law of greater structural similarity in the earlier stages of organisms becomes very evident when we look carefully into the development of flowers. Very many flowers which, when fully formed, have little resemblance to each other, are found to be exactly alike in their earlier stages. Relationships are thus indicated where they would otherwise hardly be detected.

Without entering further upon this subject, which would require several volumes for its full treatment, it need only be said here that all the floral organs are essentially alike in form and structure upon their first appearance; the sepals, petals, stamens, and pistils appear at first as small papillæ, and it is only after they have grown somewhat that the nature of the nascent organ can be determined by its shape. Moreover, it is found (as has so often been seen in the development of animals) that the rudiments of some organs which are wanting in the fully-formed flower are present in its earlier stages, a fact of no less significance in the comparative anatomy of plants than of animals.

The general appearance of the parts of the very young flower, and their development, are well shown in the accompanying figures from Hofmeister (Figs. 311–313).*

Glossology of Angiosperms.—The great number of species of Angiosperms and the multitude of forms assumed by different parts of

* The student who wishes to study this subject further may profitably consult Hofmeister's "Allgemeine Morphologie der Gewächse," Leipsic, 1868, and Payer's "Organogénie de la Fleur," Paris, 1857.

the plant, have made necessary the use of many descriptive terms, the principal ones only of which will be noticed here.

Inflorescence.—The arrangement of the flowers, whether singly, or in groups upon a more or less branched axis, is termed *inflorescence.* The branching of the axis in flower groups is almost universally mono-

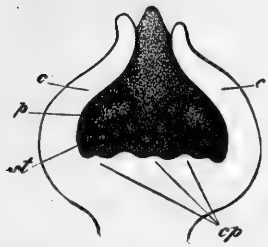


FIG. 311.

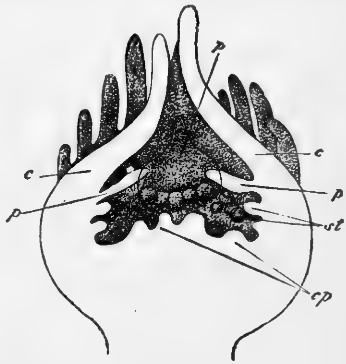


FIG. 312.

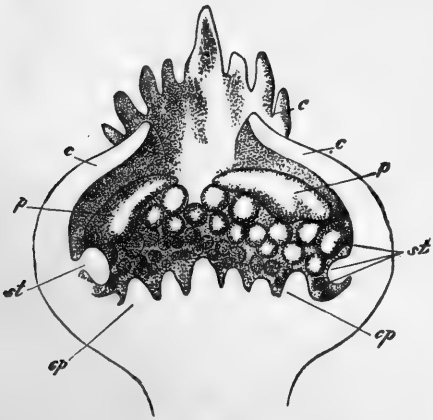


FIG 313.

Figs. 311–13.—Three successive stages in the development of the flower of the Rose (*Rosa canina*). In all the figures, *c*, *c* are the sepals; *p*, *p*, petals; *st*, stamens; *cp*, carpels or pistils. Magnified.—After Hofmeister.

podial, a few cases only (and they doubtful ones) have been regarded as dichotomous.

Monopodial flower clusters fall under the two types *Botryose* and *Cymose*, referred to in paragraph 177 (page 139). In Botryose inflores-

cence the flowers are properly lateral upon the main axis, or the secondary axes. The flowers develop in acropetal (centripetal) order, and when the axis continues to grow the cluster may become indefinitely extended, whence it is called *indeterminate.* In Cymose inflorescence every flower is properly terminal upon a main axis or one of the secondary ones. In every flower cluster the main axis is first terminated by a flower; lateral branches (secondary axes) then arise at some distance below the apex, and each of these is terminated by a flower; lateral branches terminated by flowers arise on the secondary axes, and so on. The flowers thus develop in basipetal (centrifugal) order. From the fact that every axis is terminated by a flower, such clusters are often called *determinate.* This distinction into indeterminate and determinate is, however, a misleading one, for some botryose inflorescences are in fact determinate—*e.g.*, the Umbel and Head; while, on the other hand, most of the cymose flower clusters are capable of indefinite extension, as is notably the case with the Helicoid and Scorpioid forms. It not infrequently happens that in large flower clusters a part of the branching is of one type and the remainder of the other; all such cases may be considered as examples of *mixed* inflorescence.

The most important of the terms in common use are given in the following table of inflorescences:

A. Botryose Inflorescence.

I. Flowers solitary in the axils of the leaves—
  e.g., Vinca............................**Solitary Axillary.**

II. Flowers in simple groups.
  1. Pedicellate.
    (*a*) On an elongated axis: pedicels about equal—*e.g., Mignonette*............**Raceme.**
    (*b*) On a shorter axis; lower pedicels longer—*e.g., Hawthorn*............**Corymb.**
    (*c*) On a very short axis; pedicels about equal—*e.g., Cherry*................**Umbel.**
  2. Sessile.
    (*a*) On an elongated axis—*e.g., Plantain.***Spike.**
      Var. β. Drooping, and scaly bracted—*e.g., Poplar*..................*Catkin.*
      Var. γ. Thick and fleshy—*e.g., Indian Turnip*.......................*Spadix.*
    (*b*) On a very short axis—*e.g., Clover*...**Head.**

III. Flowers in compound groups.
  1. Regular.
    (*a*) Racemes in a raceme—*e.g., Smilacina.***Compound Raceme.**
    (*b*) Spikes in a spike—*e.g., Wheat*......**Compound Spike.**
    (*c*) Umbels in an umbel—*e.g., Parsnip*..**Compound Umbel.**

(*d*) Heads in a raceme—*e.g.*, *Ambrosia*..**Heads Racemose.**
(*e*) Heads in a spike—*e.g.*, *Liatris*......**Heads Spicate.**
And so on.

2. Irregular.
Racemosely or corymbosely compound—
e.g., *Catalpa* ....**Panicle.**

Compound forms of the panicle itself are common—*e.g.*, *panicled heads* in many Compositæ, *panicled spikes* in many grasses.

B. CYMOSE INFLORESCENCE.

I. Flowers solitary; terminal—*e.g.*, *Anemone nemorosa*............................**Solitary Terminal.**

II. Flowers in clusters (Cymes).
1. Lateral branches in all parts of the flower cluster developed—*e.g.*, *Cerastium*......**Forked Cyme, or Dichasium.**

(This is the *Biparous*, and so-called *Dichotomous Cyme* of authors.)

2. Some of the lateral branches regularly suppressed.
(*a*) The suppression all on one side—*e.g.*, *Hemerocallis*.......................**Helicoid Cyme, or Bostryx.**
(*b*) The suppression alternately on one side and the other—*e.g.*, *Drosera*...**Scorpioid Cyme, or Cicinnus.**

(The last two are frequently not distinguished from one another, and are called *Monochasia, Uniparous Cymes*, or *False Racemes.*)

C. MIXED INFLORESCENCE.

1. *Cymo-Botryose*, in which the primary inflorescence is botryose, while the secondary is cymose, as in *Horsechestnut*...**Cymo-Botrys.**

(This is sometimes called a *Thyrsus.*)

2. *Botryo-Cymose*, in which the primary inflorescence is cymose, while the secondary is botryose—*e.g.*, in many *Compositæ*...............................**Botry-Cyme.**

Floral Symmetry.—The parts of the flower are mostly arranged in whorls, which are distinctly separated from each other (*cyclic* flowers); in some cases they are arranged in spirals, with, however, a distinct separation of the different groups of organs (*hemicyclic* flowers); in still other cases the arrangement is spiral throughout, with no separation of the groups of organs (*acyclic* flowers).

In cyclic flowers there are most frequently four or five whorls, viz.:

1. The *Calyx*, composed of (mostly) green *sepals*.
2. The *Corolla*, composed of (mostly) colored *petals*.
3. (4.) The *Andrœcium*, composed of one or two whorls of *stamens*.
4 or 5. The *Gynœcium*, composed of *carpels*.

These whorls usually contain definite numbers of organs in each; in many cases the numbers are the same for all the whorls of the flower (*isomerous* flower); when the numbers are different the flower is said to be *heteromerous*.

The terms which denote these numerical relations are: *monocyclic*, applied to a flower having only one cycle; *bicyclic*, two cycles; *tricyclic*, three cycles; *tetracyclic*, four cycles; *penta yclic*, five cycles, etc.; *monomerous*, applied to flowers each cycle of which contains one member; *dimerous*, two members; *trimerous*, three members; *tetramerous*, four members; *pentamerous*, five members.

These relations can be briefly indicated by using symbols and constructing floral formulæ, as follows:

Ca_5, Co_5, An_5, Gn_5 = a tetracyclic pentamerous flower;
Ca_3, Co_3, An_{3+3}, Gn_3 = a pentacyclic trimerous flower.

Most commonly the members of one whorl alternate with those of the whorls next above and below; in a few cases, however, they are opposite (or superposed) to each other. These relations may be indicated by a modification of the floral formulæ given above, as follows, where the members are alternate:

```
Gn  ____        ____        ____
An        ____        ____        ____
An  ____        ____        ____
Co        ____        ____        ____
Ca  ____        ____        ____
 B              ____
```

When they are opposite the arrangement is as follows:

```
Gn  ____  ____  ____  ____  ____
An  ____  ____  ____  ____  ____
Co  ____  ____  ____  ____  ____
Ca  ____  ____  ____  ____  ____
 B           ____
```

In both these formulæ the position of the parts of the flower with respect to the flowering axis is indicated by the position of the bract B, which is always on the anterior side, while the axis is always posterior.

When all the members on each whorl are equally developed, having the same size and form, the flower may be vertically bisected in any plane into two equal and similar halves; it is then *actinomorphic* (= regular, and polysymmetrical). When the members in each whorl

are unlike in size and form, and the flower is capable of bisection in only one plane, it is *zygomorphic* (= irregular, and monosymmetrical). In the latter there is generally more or less of an *abortion* of certain parts—*i.e.*, one or more of the sepals, petals, stamens, or pistils are but partially developed, appearing in the flower as rudiments only. Sometimes this is so marked as to result in the complete *suppression* of certain parts.

It not infrequently happens in both actinomorphic and zygomorphic flowers that entire whorls are suppressed; this gives rise to a number of terms, as follows:

When all the whorls are present (not necessarily, however, *all members* of all the whorls) the flower is said to be *complete;* when one or more of the whorls are suppressed, the flower is *incomplete.*

As to its perianth, the flower is said to be

Dichlamydeous, when both the whorls of the perianth are present;
Monochlamydeous, when but one (usually the calyx) is present;
Apetalous, when the corolla is wanting;
Achlamydeous, or *naked*, when both calyx and corolla are wanting;

As to its sexual organs, the flower is

Bisexual (or *hermaphrodite*) when stamens and pistils are present;
Unisexual, when, of the essential organs, only the stamens are present (then *staminate*), or only the pistils (then *pistillate*);
Neutral, when both stamens and pistils are wanting;

Collectively, bisexual flowers are said to be *monoclinous;* unisexual flowers, *diclinous;* while in those cases where some flowers are bisexual and others unisexual they are, as a whole, said to be *polygamous.*

Diclinous flowers are further distinguished into

Monœcious, when the staminate and pistillate flowers occur on the same plant, and
Diœcious, when they occur on different plants.

The Perianth.—In a large number of flowers the parts of the calyx and corolla (sepals and petals) are distinct—*i.e.*, not at all united to one another; such are said to be *chorisepalous* * as to the calyx, and *choripetalous* as to the corolla. The terms *polysepalous* and *polypetalous* are the ones most commonly used in English and American books on botany, although they manifestly ought to be used as numerical terms. *Eleutheropetalous* † and *dialypetalous* ‡ are also somewhat used, especially in German works.

The numerical terms usually employed are *mono-*,§ *di-*, *tri-*, *tetra-*,

---

* From Greek χωρίζειν, to sever, to separate.

† From Greek ελεύθερος, free.

‡ From Greek διαλύειν, to part asunder.

§ The terms *monosepalous* and *monopetalous* were formerly used with a different meaning from that given here; they were applied to the forms now called gamosepalous and gamopetalous. This use, errone-

penta-sepalous, etc., and *mono-*, *di-*, *tri-*, *tetra-*, *penta-petalous*, etc., meaning of one, two, three, four, five sepals or petals respectively. *Polysepalous* and *polypetalous* are properly used to designate " a considerable but unspecified number " of sepals or petals.*

In some flowers the sepals or petals, or both, are united to one another, so that the calyx and corolla are each in the form of a single tube or cup. This union of similar parts is called *coalescence*. The terms *gamosepalous* † and *gamopetalous* (or *sympetalous*) are used in such cases. *Monosepalous* and *monopetalous*, still used in this sense in many descriptive works, should be reserved for designating the number of sepals or petals in calyx and corolla respectively.

Not infrequently the calyx and corolla are connately united to each other for a less or greater distance. This union of dissimilar whorls is termed *adnation*, and the calyx and corolla are said to be adnate to each other.

The Andrœcium.—The number of stamens in the flower or the andrœcium is indicated by such terms as

Monandrous, signifying of one stamen ;

Diandrous, of two stamens ;

Triandrous, of three stamens ;

Tetrandrous, of four stamens—when two of the stamens are longer than the other two, the andrœcium is said to be *didynamous* ;

Pentandrous, of five stamens ;

Hexandrous, of six stamens ; when four are longer than the remaining two, the andrœcium is said to be *tetradynamous*.

Other terms of similar construction are used, as *heptandrous*, seven stamens ; *octandrous*, eight ; *enneandrous*, nine ; *decandrous*, ten ; *dodecandrous*, twelve ; and *polyandrous*, many or an indefinite number of stamens.

The stamens may be in a single whorl (*monocyclic*), in which case, if agreeing in number with the rest of the flower, the andrœcium is said to be *isostemonous* ; they are often in two whorls (*bycyclic*), and when each whorl agrees with the numerical plan of the flower, the andrœcium is *diplostemonous*.

The various kinds of coalescence require the use of special terms. When there is a coalescence of the filaments the andrœcium is

Monadelphous, when the stamens are united into one set ;

Diadelphous, when united into two sets ;

Triadelphous, when united into three sets, etc.

---

ous as it obviously is, has not yet been abandoned in works on descriptive botany.

* Dr. Gray throws the weight of his authority in favor of this use of these terms (" Structural Botany," 1879, p. 244).

† From Greek γάμος, union.

When there is a coalescence of the anthers the andrœcium is *syngenesious* or *synantherous.*

The stamens may be adnate to the petals, when they are *epipetalous;* in some cases they are adnate to the style of the pistil, as in the Orchids; such are said to be *gynandrous.*

The principal terms which designate the structural relation between the anther and filament in individual stamens are:

Adnate, applied to anthers which are adherent to the upper or lower surface (anterior or posterior) of the filament; when on the upper surface the anthers are *introrse;* when on the lower, *extrorse.*

Innate, applied to anthers which are attached laterally to the upper end of the filament, one lobe being on one side, the other on the opposite one. The part of the filament between the two anther-lobes is designated the *connective;* it is subject to many modifications of form, and often becomes separable by a joint at the base of the anther from the rest of the filament.

Versatile is applied to anthers which are lightly attached to the top of the filament, so as to swing easily; these may also be *introrse* or *extrorse.*

The Gynœcium.—The Gynœcium is made up of one or more *carpels* (*carpids* or *carpophylla*)—*i.e.*, ovule-bearing phyllomes, and it is said to be *mono-*, *di-*, *tri-*, *tetra-*, *penta-*, etc., and *poly-carpellary,* according as it has one, two, three, four, five, to many carpels. In old books the terms *monogynous, digynous, trigynous,* etc., meaning of one, two, three, etc., carpels, are used instead of the more desirable modern ones. When the carpels are more than one they may be distinct, forming the *apocarpous* gynœcium; or they may be coalescent into one compound organ, the *syncarpous* gynœcium. In the former case the term *pistil* is applied to each carpel, and in the latter to the compound organ. Pistils are thus of two kinds, *simple* and *compound;* the simple pistil is synonymous with carpel; the compound pistil with syncarpous gynœcium.

In the simple pistil the ovules actually grow out from the united margins (the *ventral suture*) of the carpophyllum; the internal ridge or projection upon which they are borne is the *placenta.* Sometimes the ovules are *erect—i.e.,* they grow upward from the bottom of the ovary—and when single appear to be direct continuations of the flower axis (Fig. 304). *Suspended* ovules—*i.e.*, those growing from the apex of the ovary cavity—are also common.

In compound pistils the coalescence may be, on the one hand, of closed carpels, and on the other of open carpels. In the former case the pistil has generally as many *loculi* (cavities or cells) as there are carpels; this is expressed by the terms *uni-*, *bi-*, *tri-*, *quadri-*, and so on to *multilocular.* Such pistils have *axile* placentæ—*i.e.*, they are gathered about the axis of the ovary, *e.g.*, *Hypericum.* In the case of compound pistils formed by the coalescence of open carpels, the margins only of the

latter unite, forming a common ovary cavity ; here the placentæ generally occur along the sutures, and are said to be *parietal—i.e.*, on the walls. Between such unilocular pistils and the multilocular ones described above there are all intermediate gradations. In one series of gradations the placentæ project farther and farther into the ovary cavity, at last meeting in the centre, when the pistil becomes multilocular with axile placentæ. On the other hand, a multilocular pistil sometimes becomes unilocular by the breaking away of the partitions during growth. In such a case the placentæ form a free central column, commonly called a *free central placenta.*

In other cases a free placental column of an entirely different origin occupies the axis of a unilocular, but evidently polycarpellary pistil. In *Anagallis*, for example, the placental column grows from the base of the ovary cavity, and there is at no time a trace of partitions (see illustrations of the Order Primulaceæ, p. 507).

The Gynœcium may be free from all the other organs of the flower, which are then said to be *hypogynous*,* and the gynœcium itself *superior.* Sometimes the growth of the broad flower-axis stops at its apex long before it does so in its marginal portions ; a tubular ring is thus formed, carrying up calyx, corolla, and stamens, which are then said to be *perigynous*,† and the gynœcium *half inferior.* These terms are used also in the cases where the gynœcium is similarly surrounded by the tubular sheath composed of adnate calyx, corolla, and andrœcium. In some nearly related cases, in addition to the structures described above as perigynous, there is a complete fusion of the calyx, corolla, and stamen-bearing tube with the gynœcium, so that the ovule-bearing portion of the latter is below the rest of the flower, *e.g.*, Compositæ. The perianth and the stamens are said to be *epigynous*‡ in such flowers, and the ovary is *inferior.* Some cases of epigyny are doubtless to be regarded as due to the adnation of the calyx, corolla, stamens, and ovaries ; in others, the ovaries are adnate to the hollow axis which bears the perianth and stamens ; in still others, it seems probable that the hollow axis is itself ovule-bearing, and that the true carpels are borne on its summit.

Certain terms descriptive of relations between the stamens and pistils which have recently come into use require explanation here.

In many flowers the stamens and pistils do not mature at the same time, such are said to be *dichogamous ;* when the stamens mature before the pistils the flower is *proterandrous ;* and when the pistils mature before the stamens they are *proterogynous.*

In some species of plants there are two or three kinds of flowers,

---

* From Greek ὑπό, under, and γυνή, female—*i.e.*, the pistil.
† From the Greek περί, about, etc.
‡ From the Greek ἐπί, upon, etc.

differing as to the relative lengths of the stamens and styles; these are called *heterogonous** or *heterostyled.* When there are two forms, viz., one in which the stamens are long and the styles short, and the other with short stamens and long styles, the flowers are said to be *dimorphous,* or more accurately *heterogonous dimorphous,* and the forms are distinguished as *short-styled* and *long-styled* When, as in some species of Oxalis, there are three forms, viz., long-, mid-, and short-styled, the term *trimorphous* (or better *heterogonous trimorphous*) is used.

The Fruit.—The fruit may include (1) only the ripened ovary with its contained seeds—*e g.*, the bean; or (2) these with an adnate calyx or receptacle—*e.g.*, the apple. Many changes frequently take place in ripening, such as (1) an increase in the number of cells by the formation of false partitions, or (2) a decrease in their number by the obliteration of some; (3) the growth of wings or prickles upon the exterior of the ovary; (4) the thickening and formation of a soft and juicy pulp; (5) the hardening of some portions of the ovary wall by the development of sclerenchyma; (6) the thickening and growth of the calyx or receptacle.

In cases where in the ripening the ovary walls remain thin, and eventually become dry, the fruits are said to be *dry*—*e.g.*, in the bean; where the walls become thickened and more or less pulpy, they are *fleshy*—*e.g.*, the peach. These terms are also used in reference to the fruit when it includes an adnate calyx or receptacle. In many fleshy fruits (developed from carpels) the inner part of the pericarp wall is hardened; the two layers are then distinguished as *exocarp* and *endocarp;* when there are three layers the middle one is the *mesocarp.*

The opening of the fruit in order to permit the escape of the seeds is called its *dehiscence,* and such fruits are said to be *dehiscent;* those which do not open are *indehiscent.* In fruits developed from single carpels dehiscence is generally through the ventral or dorsal suture, or both; in those developed from compound pistils the partitions may split, and thus resolve each fruit into its original carpels (*septicidal dehiscence*); or the dorsal sutures may become vertically ruptured, thus opening every cell (loculus) by a vertical slit (*loculicidal dehiscence*). Among the other forms of dehiscence only that called *circumcissile* and the *irregular* need be mentioned; in the former a transverse slit separates a lid or cap, exposing the seeds; in the latter an irregular slit forms at a certain place, and through this the seeds escape.

The principal fruits may be distinguished by the brief characters given in the following table:†

---

* Proposed by Dr. Gray, *Am. Naturalist,* Jan., 1877.

† This is based upon Dr. Dickson's classification as modified by Professor Balfour in the article "Botany" in the ninth edition of the "Encyclopædia Britannica," Vol. IV., p. 153.

A. Monogynœcial fruits, formed by the gynœcium of one flower.

I. **Capsulary fruits.** Dry, dehiscent, formed from one pistil.

1. Monocarpellary.
   (*a*) Opening by one suture—*e.g., Caltha*.......FOLLICLE.
   (*b*) Opening by both sutures—*e.g., Pea*........LEGUME.
2. Bi-polycarpellary—*e.g., Viola*..................CAPSULE.
   Var. *a.* Dehiscence circumcissile—*e.g., Anagallis*.............................Pyxis.
   Var. *b.* Dehiscence by the falling away of two lateral valves from the two persistent parietal placentæ — *e.g., Mustard*..............................Silique.

II. **Schizocarpic fruits.** Dry, breaking up into one-celled indehiscent portions.

1. Monocarpellary, dividing transversely—*e.g., Desmodium*..................................LOMENT.
2. Bi-polycarpellary.
   (*a*) Dividing into achene-like or nut-like parts (*nutlets*), no forked carpophore—*e.g., Lithospermum*................................CARCERULUS.
   (*b*) Dividing into two achene-like parts (*mericarps*), a forked carpophore between them —*e.g., Umbelliferæ*......................CREMOCARP.

III. **Achenial fruits.** Dry, indehiscent, one-celled, one or few seeded, not breaking up.

1. Pericarp hard and thick—*e.g., Oak* ....NUT.
2. Pericarp thin—*e.g., Sunflower*.................ACHENE.
   Var. *a.* Pericarp loose and bladder-like—*e.g., Chenopodium*......................Utricle.
   Var. *b.* Pericarp consolidated with the seed—*e.g., Grasses*......................Caryopsis.
   Var. *c.* Pericarp prolonged into a wing—*e.g., Ash*..............................Samara.

IV. **Baccate fruits.** Fleshy, indehiscent; seeds in pulp.

1. Rind firm and hard—*e.g., Pumpkin*.............PEPO.
2. Rind thin—*e.g., Gooseberry*...................BERRY.

V. **Drupaceous fruits.** Fleshy, indehiscent; endocarp indurated usually stony.

1. One stone, usually one-celled—*e.g., Cherry*......DRUPE.
2. Stones or papery carpels, two or more—*e.g., Apple*...................................POME.

VI. **Aggregate fruits.** Polycarpellary; carpels always distinct. The forms of these are not well distinguished. In many Ranuncu

laceæ there are numerous achenes on a prolonged receptacle ; in Magnolia numerous follicles are similarly arranged ; in the raspberry many drupelets cohere slightly into a loose mass, which separates at maturity from the dry receptacle ; in the blackberry similar drupelets remain closely attached to the fleshy receptacle ; in the strawberry there are many small achenes on the surface of the fleshy receptacle ; finally, in the rose several to many achenes are enclosed within the hollow and somewhat fleshy receptacle.

B. Polygynœcial fruits, formed by the gynœcia of several flowers.

1. A spike with fleshy bracts and perianths—*e.g.*, *Mulberry*.......................................SOROSIS.
2. A spike with dry bracts and perianths—*e.g.*, *Birch*.......................................STROBILE.
3. A concave or hollow, fleshy receptacle, enclosing many dry gynœcia—*e.g.*, *Fig*................SYCONUS.

The Seed.—Many of the terms used in the description of the ovule are applied also to the seed. However, the modifications which most of the parts undergo render necessary some additional terms. Thus the outer integument is generally so thickened and hardened that it is commonly called the *testa.* The inner is sometimes called the *tegmen.* In some seeds the outer coat becomes fleshy, in which case they are baccate (berry-like) ; in others the outer part of the testa is fleshy and the inner hardened, so that the seed is drupe-like (drupaceous). Occasionally an additional coat forms around the ovule after fertilization ; it differs somewhat in nature in different plants, but all are commonly included under the name *aril—e.g.*, May Apple.

The testa may be prolonged into one or more flat extensions ; such a seed is *winged—e.g.*, Catalpa. Its epidermal cells may be prolonged into trichomes, forming the *comose* seed—*e.g.*, cotton.

The embryo either occupies the whole of the seed cavity, in *exalbuminous* seeds, or it lies in or in contact with the endosperm, in the *albuminous* seeds. It is *straight—e.g.*, the pumpkin; or variously curved and folded—*e.g.*, in *Erysimum*, where the cotyledons are *incumbent,* and in *Arabis,* where they are *accumbent.*

537.—The Tissues of Angiosperms.—The epidermis of Angiosperms does not differ in any marked way from that of the Gymnosperms and the Pteridophytes. The principal differences are that, as a rule, the stomata are more numerous, and the trichomes, which are much more commonly present, show greater variations in form and structure. It is noticeable, furthermore, that in both these points the Dicotyledons excel the Monocotyledons.

538.—The tissues of the fundamental system in the Angiosperms are, in general, sharply set off from those of the epidermal and fibro-vascular systems. In the annual stemmed species the fundamental tissues constitute the greater part of the stems, but in perennial-stemmed species there is proportionately less of these, and more of the fibro-vascular tissues; in the former the principal tissue in the fundamental system is parenchyma, which occupies the interfascicular spaces, as well as the greater part of that lying between the bundles and the epidermis—*i.e.*, in the cortical region. In perennials, on the contrary, the interfascicular spaces are in many cases occupied by sclerenchyma, and the cortical region either entirely disappears (as in Dicotyledons) or it becomes filled with sclerenchymatous or fibrous tissue.

In the leaves the fundamental system rarely includes more than chlorophyll-bearing parenchyma, while in the parts of flowers a similar tissue is found, which is, however, generally wanting in chlorophyll. The succulent parts of fruits, whether phyllome or caulome structures, are composed of parenchyma of the fundamental system.

539.—The fibro-vascular bundles of the stems of Angiosperms are entirely of De Bary's "collateral" class—that is, each bundle in cross-section presents more or less distinctly two sides, viz., xylem and phloëm. Each of these sides, as previously described (paragraph 147), generally contains parenchymatous, fibrous, and vascular tissues, the latter tracheary in the xylem, and sieve in the phloëm.

540.—The disposition of the bundles in the Angiosperms is for the most part dependent upon the position of the leaves. Nearly all the first-formed bundles are of the kind termed "common bundles"—that is, they extend on the one hand into the leaf, and on the other down into the stem. In Fig. 314 there pass down from each leaf three bundles; at the lower internode these are, on the left, *a, b, c,* and on the right, *d, e, f.* At the next internode, where the leaves stand at right angles to the lower ones, there are three bundles again, *g, h, i,* and *k, l, m;* these are largest at their points of curvature, and they dwindle in size as they pass downward and finally unite with the bundles from the lower

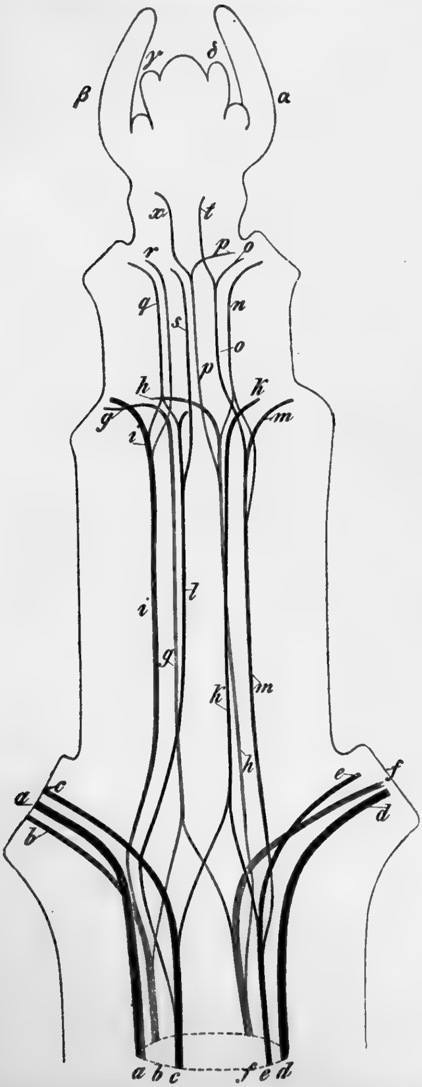


Fig. 314.—Showing the disposition of the fibro-vascular bundles in the stem of *Clematis Viticella*. *a, b, c,* — *d, e, f,* the bundles from the lower pair of leaves; *g, h, i,* — *k, l, m,* the bundles from the second pair of leaves; *n, o, p,* — *q, r, s,* the bundles from the third pair of leaves; *x* and *t*, the median bundles of the fourth pair of leaves; *α, β,* — *γ, δ,* pairs of rudimentary leaves not yet supplied with bundles.—After Nägeli.

pair of leaves. The bundles from the third internode pass downward, and in like manner join those from the second pair of leaves, and so on. Thus in such a stem every bundle passes downward through one internode before joining another, and in any internode all the bundles are derived from the leaves at its summit.

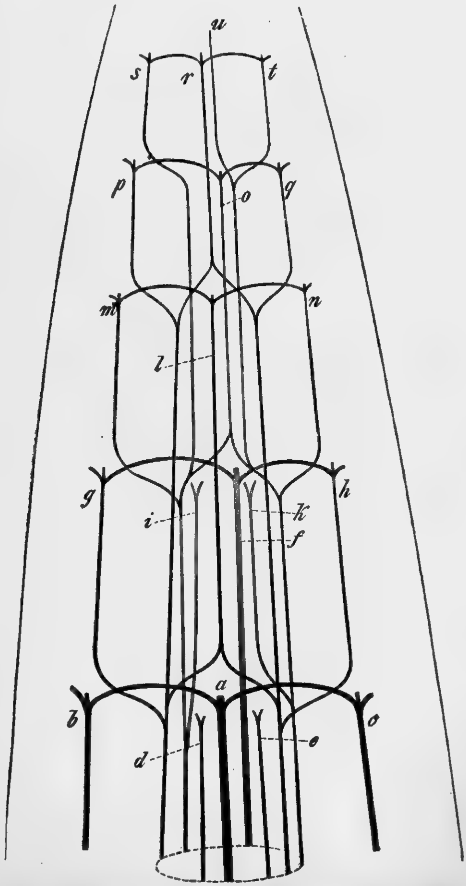


Fig. 315.—Diagram showing the arrangement of the fibro-vascular bundles in the stem of *Lathyrus Pseuda-phaca*. The bundles nearest the observer are figured darker, those farthest away lighter.—After Nägeli.

In Fig. 315, with a similar arrangement in the main, there are some complications. The lateral leaf-bundles (*b, c* in the lower internode, and *g, h* in the next one) pass downward to the next node, where they unite with other descending bundles; and the median bundles, *a, f, l, o, r, u,* pass down through two internodes, and then fork right and left, and unite with other descending bundles. Thus in any internode there are bundles from at least three leaves. This is shown in the cross-section of the next to the lower internode (Fig. 316), in which the bundles *h, f, g, k, i* pass

into the second leaf—*i.e.*, the leaf at the summit of the internode under consideration; the bundles *l, m, n* descend from the leaf next above, and *p* and *q* from the one still higher.

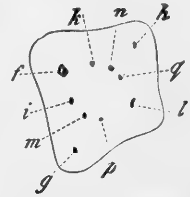


Fig. 316. — Cross-section of the next to the lower internode of Fig. 315, showing the arrangement of the bundles, the lettering as in Fig. 315. —After Nägeli.

541.—We may get a clearer idea of the mutual relations of the bundles if we conceive the bundle-cylinder to be split down on one side, and spread out upon a plane. In Fig. 317 we have such a diagrammatic representation of the arrangement of the bundles in the stem of *Stachys angustifolius.* Here each leaf sends down two bundles, which pass through two internodes and then unite with other descending bundles at their middle points. The fibro-vascular cylinder is thus composed when complete of repeatedly branching bundles. A cross-section (Fig. 318) through the stem at some distance above the lower leaves in Fig. 317 shows that each internode contains bundles from two pairs of leaves—*i.e.*, those at its summit and those at the summit of the one above. In Fig. 318 the pairs of bundles marked *c* and *d* descend from the leaves *c* and *d*, while those marked *e* and *f* pass down from the leaves one internode higher up.

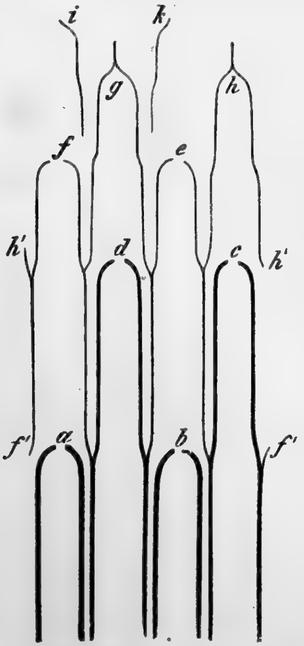


Fig. 317.—Diagram showing the arrangement of the fibro-vascular bundles in *Stachys angustifolius.* *a, b,* —*d, c,* —*f, e,* — *g, h,* — *i, k*, the points from which the successive pairs of leaves spring.—After Nägeli.

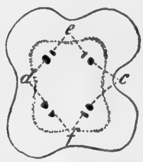


Fig. 318. — Cross-section of the next to the lower internode in Fig. 317, showing the disposition of the bundles, the lettering as in Fig. 317.—After Nägeli.

In a similarly constructed diagram of the fibro-vascular cylinder of *Iberis amara* (Fig. 319, projected upon a series of transverse and vertical lines to

indicate the nodes and the vertical ranks of leaves) the single bundles which descend from the leaves are shown to pass through from ten to twelve internodes before uniting with

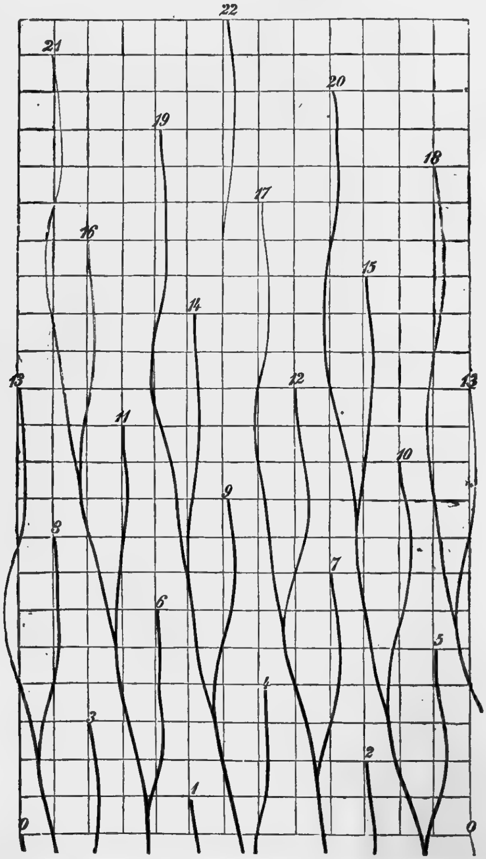


Fig. 319.—Diagram showing the arrangement of the fibro-vascular bundles in 22 internodes of the stem of *Iberis amara.*—After Nägeli.

other bundles. It is seen, moreover, that there are running through the stem five series of branching bundles, which are not quite vertical, but slightly spiral. In Fig. 320 is shown the appearance of an actual section of the stem taken be-

tween the fifth and sixth leaves of the preceding figure. The bundles are numbered as in Fig. 319.

542.—In a comparatively small number of instances there are fibro-vascular bundles in the stem which have no connection with the leaves. These are known as cauline bundles.

543.—In the Monocotyledons and many herbaceous Dicotyledons, the fibro-vascular bundles are closed—that is, there is no zone of meristem tissue left between the xylem and phloëm after these have passed over into permanent tissues. There is, as a consequence, a definite period of growth for the bundles, and when any bundle has fully formed all its tissues, no further development can take place in it. This generally results in definitely limiting the growth of the internodes, and in consequence such plants are as a rule short-lived. The perennial woody-stemmed Dicotyledons, and some of the herbaceous annuals, possess bundles which are open—that is, there is left between the xylem and the phloëm a zone of meristem tissue which continues to grow long after the other parts of the bundle have passed over into permanent tissues. Plants with such bundles may live and continue to grow for an indefinite time.

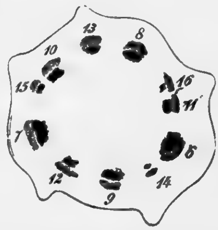


Fig. 320.—Cross-section of the stem of which Fig. 319 is the diagram, taken above the fifth leaf.—After Nägeli.

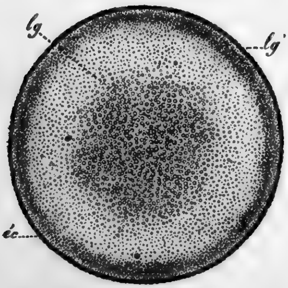


Fig. 321.—Cross-section of the stem of a palm. *ec*, cortical zone; *lg*, the softer interior portion of the stem; *lg'*, the harder peripheral portion.—After Duchartre.

544.—A cross-section of the stem of a Palm (Fig. 321) shows it to be composed of parenchymatous tissue traversed by myriads of fibro-vascular bundles, which descend from the crown of leaves. Each leaf sends down from its broad insertion numerous bundles, which, in a vertical section, are seen first to pass in toward the centre of the stem, and then to curve downward and finally outward. The centre of the stem is thus softer than the peripheral portion, as in the latter the descending

bundles are more numerous. In such a stem it is evident that there can be no considerable increase in thickness after it is once formed, and we consequently find that palms take a long time for the formation of a broad bud or growing point (*punctum vegetationis*), and afterward push up a cylindrical stem in which little change subsequently takes place.

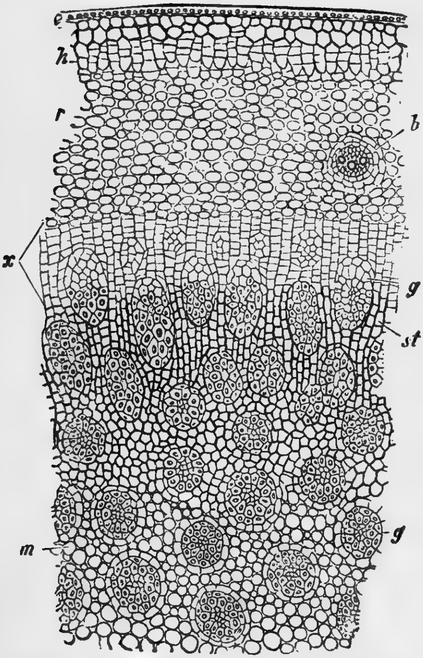


Fig. 322.—Cross-section of stem of *Dracæna*. *e*, epidermis; *k*, cork; *r*, cortex; *b*, a fibro-vascular bundle bending out to a leaf; *m*, parenchyma of the fundamental system; *g*, *g*, fibro-vascular bundles; *x*, meristem zone of the fundamental system in which new bundles and tissues are forming.—After Sachs.

In the Dragon trees (*Dracæna*, sp.) and some other Monocotyledons, there is a thick layer of parenchymatous cortex between the column of fibro-vascular bundles and the epidermis (Fig. 322, *r*), and in the deeper layers of this a persistent meristem tissue is found (Fig. 322, *x*). In this meristem there are formed fibro-vascular bundles, which lie parallel to those already formed, and in this way the stem slowly increases in thickness.

545.—In those Dicotyledons whose stems increase in thickness there always develops soon a layer of meristem tissue, which connects the cambium layer of one fibro-vascular bundle with that of the other (Fig. 323). This is made easier from the fact that in most (but not all) Dicotyledons the bundles lie at nearly the same depth beneath the epidermis on all sides of the stem, thus forming a cylinder, or in cross-section, a ring, as in Fig. 323. Both the fascicu-

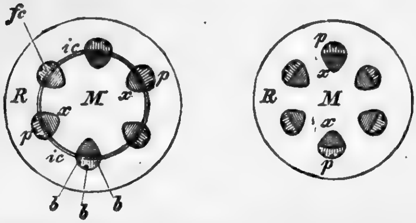


Fig. 323.—Diagrams of dicotyledonous stems as seen in cross-section. *R*, the cortical, *M*, the medullary portion of the fundamental system ; *p*, the phloëm ; *x*, the xylem ; *b*, *b*, *b*, groups of bast fibres ; *fc*, the fascicular, *ic*, the interfascicular cambium.—After Sachs.

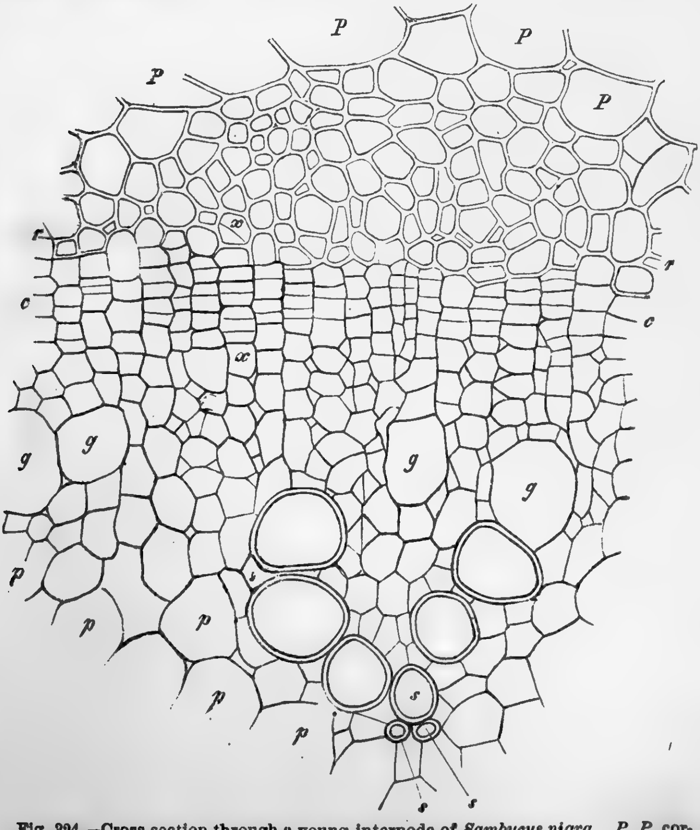


Fig. 324.—Cross-section through a young internode of *Sambucus nigra*. *P*, *P*, cortical parenchyma ; *p*, *p*, parenchyma of the pith ; between *r*—*r* and *P*—*P*, sieve tissue ; *g*, *g*, pitted vessels ; *s*, *s*, and above, spiral vessels ; *c*—*c*, the cambium zone. × 220.—After De Bary.

lar and interfascicular cambium layers are composed of elongated cells, which multiply by fission in a tangential direction, and thus give rise to radiating rows of cells (Figs. 324 and 325). In a tangential section the cambium cells present an elongated outline, and their extremities are usually more or less oblique (Fig. 326). From these cells there develop various tissues. Thus, on the one side, the phloëm parenchyma, sieve and fibrous tissues may be produced by more or less great modifications (Fig. 327). On the other side (the xylem side) new vessels, fibres, and parenchyma are also developed (Fig. 328). The development of these tissues begins in the inner and outer layers of the cambium, and advances toward the central layers. It never happens, however, that all the cambium layers pass over into permanent tissues, there always remaining one or a few meristem layers.

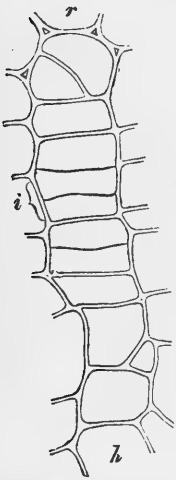


Fig. 325.—The row of cells marked $x-x$ in Fig. 324; r, phloëm: h, xylem; at i are seen the fissions of the cambium cells. × 600. — After De Bary.

546.—A study of Figs. 326–328 will show the probable mode of development of the permanent tissues from the meristem tissue of the cambium. It is evident from a comparison of Figs. 326 and 327 that the phloëm parenchyma is produced by the formation of several transverse partitions in each cambium cell, and it is probable that in many cases there is a direct conversion of cambium cells into sieve tubes. That the cambium cells may be converted directly into tracheïdes is evident from Fig. 326, and also Fig. 75 (p. 84). In Fig. 328 it is plain that the fibrous tissue (*lf*) and tracheïdes (*t*) have the same origin, and the indications are that even the large pitted vessels (*gg*) are formed from cambium cells by the great increase in the diameter of the latter, the thickening of their vertical walls, and the partial or complete absorption of their transverse walls. The origin of the xylem parenchyma from cam-

bium cells by the formation of transverse partitions is very clear in this figure.

547.—In the trees and shrubs of cold climates, or of those in which there is one annual period of growth, followed by a period of rest or the cessation of growth, the

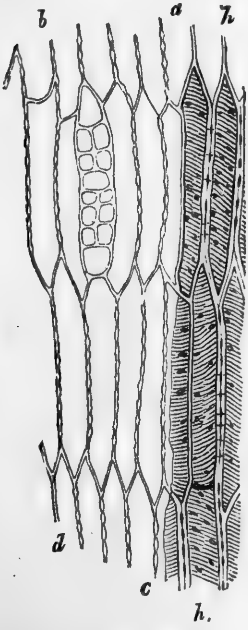


FIG. 326.

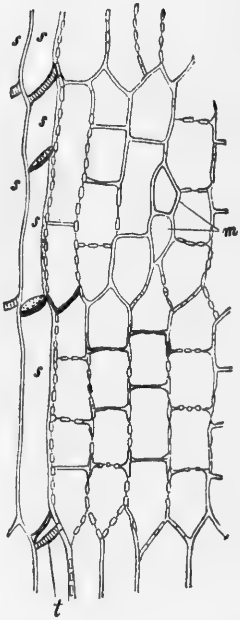


FIG. 327.

Fig. 326. A tangential section of the cambium region of *Cytisus Laburnum*. *a*, *b*, *c*, *d*, cambium cells enclosing the section of a medullary ray; *h*, *h*, tracheïdes belonging to the xylem. × 145.—After De Bary.

Fig. 327.—Tangential section of the inner phloëm region of the same stem as Fig. 326. *s*, *s*, *s*, sieve vessels; *m*, section of a small medullary ray; the remaining parts of the figure are phloëm parenchyma. × 145.—After De Bary.

processes described above take place each year, giving rise thus to an annual layer of xylem (wood) outside of the previously formed xylem cylinder, and an annual layer of phloëm (bark) inside of the phloëm cylinder. In the wood these layers are generally quite well marked, and in cold climates they enable us to determine with accuracy the age

of trees and shrubs (Fig. 329). The layers of the bark are rarely well marked, and they generally become soon obliterated by irregular corky growths in the substance of the bark

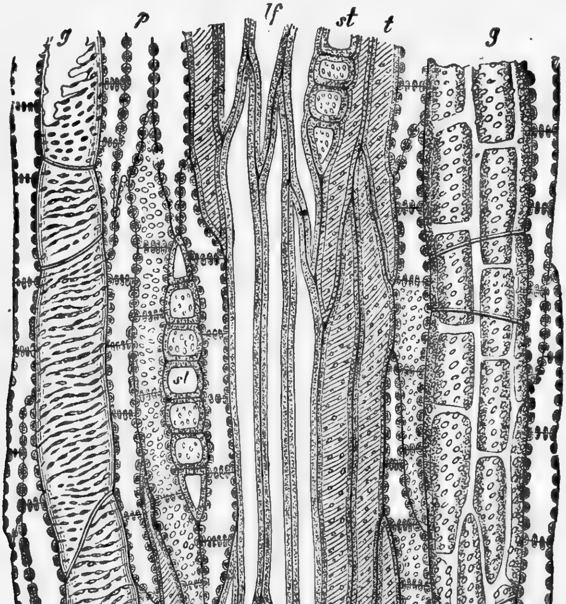


Fig. 328.—Tangential section of the stem of *Ailanthus glandulosus*, through the secondary xylem: *g*, *g*, pitted vessels; *p*, *p*, xylem parenchyma; *st*, *st*, medullary rays in cross-section; *lf*, fibrous tissue (wood cells); *t*, tracheïdes. Highly magnified. —After Sachs.

itself. They are, moreover, ruptured by the increase in the diameter of the woody cylinder, and soon decay and fall away. It thus happens that while the annual layers of the wood are constantly increasing in number, reaching in ex-

treme cases more than a thousand,* the bark rarely shows more than a few distinct layers, and its thickness is generally very much less than that of the former.

From what has been said it is seen that a dicotyledonous stem several years old is composed of a series of larger and larger continuous woody shells (Fig. 330, 1, 2, 3, 4, 5) surrounded by a corresponding series of bark shells, which are smaller and smaller (Fig. 330, 5′, 4′, 3′, 2′, 1′).

548.—The Medullary Rays. In the young dicotyledonous stems there are thick masses of parenchyma, which connect the cortical with the medullary (pith) portion of the fundamental system of tissues (Fig. 323). However, as the fibro-vascular bundles increase, these masses become thinner, until they are mere plates, often not more than one or two, or at most a few cells in thickness (Figs. 326–7–8). From their appearance and position they have long borne the name of Medullary Rays. In the young stem their cells may be parenchymatous, but in older ones they are frequently sclerenchymatous. Viewed in a radial section of the stem, they are generally seen to be elongated in the direction of the radius, having the outlines of right-angled quadrilaterals. In the increase of the diameter of the stem there is always an increase in the length of the medullary rays, both in their bark and wood portions; and when from their divergence a considerable space intervenes between two rays, one or more new ones arise between them; thus while there may be no more than four or five rays in the young plant, it may when old have hundreds of them in its circumference (Fig. 329).

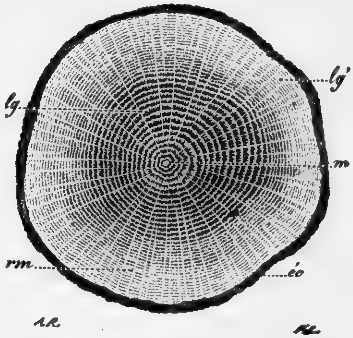


Fig. 329.—Cross-section of the stem or an oak (*Quercus Robur*) thirty-seven years old. *m*, pith; *lg*, heart-wood; *lg′*, sap-wood; *rm*, medullary rays; *ec*, the bark. Much reduced. —After Duchartre.

What has been said of the tissues of the Angiosperms must suffice to

*** In the Lime (*Tilia Europæa*) 1076 and 1147, and in the Oak (*Quercus Robur*) 1080 and 1500, according to De Candolle.**

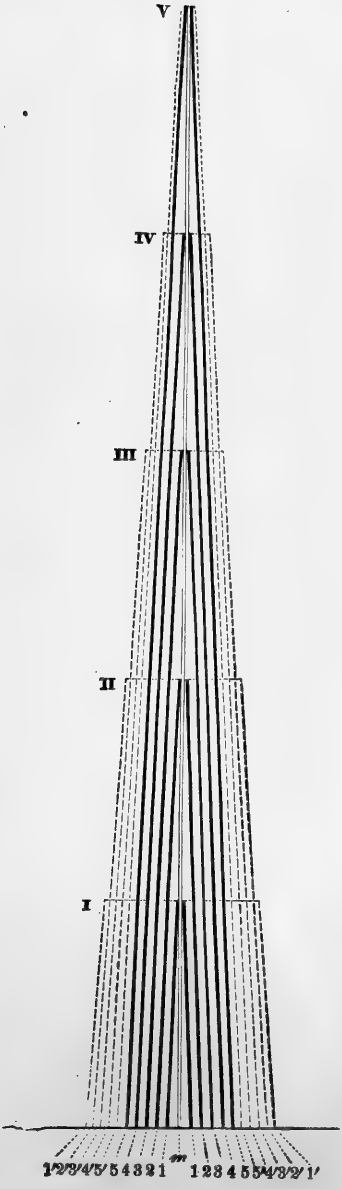


Fig. 330.—An ideal vertical section of a dicotyledonous stem, five years old. *I.*, *II.*, *III.*, *IV.*, *V.*, the successive heights attained in its annual growth; *m*, pith; 1, 2, 3, 4, 5, the annual xylem layers corresponding respectively to the annual phloëm layers, 1', 2', 3', 4', 5'.—After Duchartre.

introduce the student to their study. For further details, he is referred to De Bary's admirable treatise, "Vergleichende Anatomie der Vegetationsorgane der Phanerogamen und Farne," in which copious references are given. The publications of Russow will also be found to be of great value to the student.

549.—The systematic arrangement of the Angiosperms is by no means settled. The one mostly followed in England and this country is a modification of De Candolle's system (A.D. 1813), which was itself a modification of Jussieu's (A.D. 1789), which in turn was based upon the general system proposed by Ray (A.D. 1703). In the "Genera Plantarum," now publishing by Bentham and Hooker, and in the English edition of Le Maout and Decaisne's "General System of Botany," we have the most recent modifications of the Candollean system. On the continent of Europe other systems have been used more or less, and it is probable that among these are to be found the best groupings of Angiosperms to indi-

cate their real affinities. Unfortunately for us, however, none of our systematic manuals follow any of the Continental systems; we are compelled, therefore, to use for the present the prevailing form of the Candollean system. In this book the sequence of the groups is the reverse of that in most American and English books, in order to bring the arrangement of Angiosperms into harmony with that of the rest of the vegetable kingdom.

Sub-Class I. Monocotyledones.

(*Endogenæ* of De Candolle.*)

550.—In these plants the first leaves of the embryo are alternate, hence we say that they have one cotyledon. The venation of the leaves is for the most part such that the veins run more or less parallel to one another, and when they anastomose enclose four-sided areolæ; rarely, however, their veins are irregularly distributed, and they anastomose so as to form an irregular network.

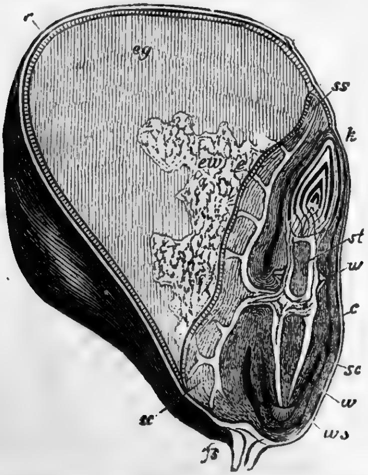


Fig. 331.—Longitudinal section of the seed of Indian corn (*Zea Mais*). *c*, adherent wall of the ovary; *n*, remains of the style; *fs*, base of the ovary; all the remainder of the figure is the true seed; *eg*, *ew*, endosperm; *sc*—*ss*, cotyledon of embryo; *e*, its epidermis; *k*, plumule; *w* (below), the main root; *ws*, the root-sheath; *w* (above), adventitious roots springing from the first internode of the stem. × 6.—After Sachs.

The germination of Monocotyledons may be illustrated by a couple of examples. In the seed of the Indian corn the embryo lies partly imbedded in one side of the large endosperm (Fig. 331). The first leaf of the young plant (the cotyledon or scutellum, Fig. 331, *sc*) has its broad dorsal surface in contact with the endosperm; anteriorly

* From the Greek ἔνδον, within, and γένειν, to bring forth. The name was given under the false impression that these plants were "inside growers," and the Dicotyledons "outside growers."

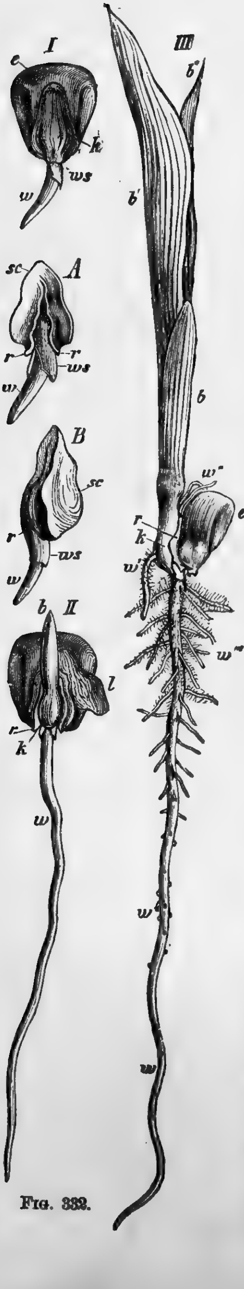


FIG. 332.

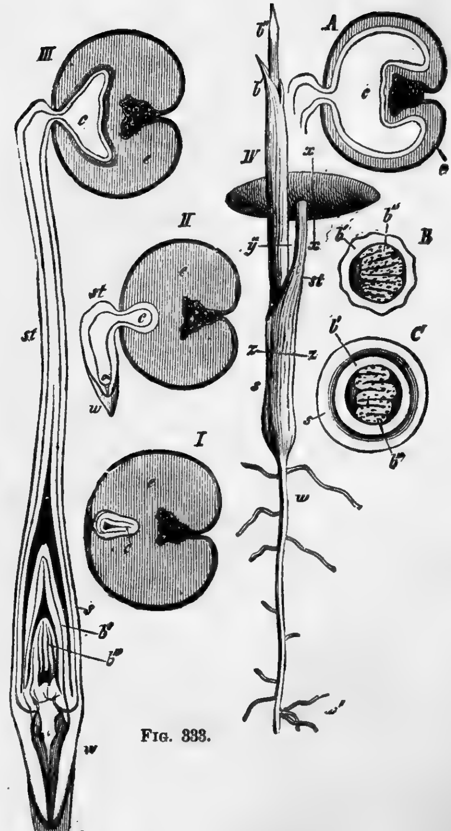


FIG. 333.

Fig. 332.—Germination of Indian corn. *I.*, *II.*, *III.*, successive stages. *A* and *B*, front and side views of a separated embryo. In the figures, *w*, the primary root; *ws*, its root-sheath; *w′*, *w″*, adventitious roots; *w‴*, lateral roots springing from the main root; *e*, part of seed filled with endosperm; *sc*, cotyledon; *r*, its open margins; *k*, the plumule; *b*, *b′*, *b″*, leaves of young plant; *l*, fragment of wall of ovary. Natural size.—After Sachs.

Fig. 333.—Germination of the Date (*Phœnix dactylifera*). *I.*, transverse section of seed; *c*, embryo; *e*, endosperm. *II.*, *III.*, sections of germinating seeds; *c*, apex of cotyledon developing into an absorbing organ; *st*, stalk of cotyledon; *s*, sheath of cotyledon; *b′*, *b″*, leaves; *w*, root; *w′*, lateral roots; *h*, root-cap. *IV.*, young plant, natural size, the lettering as in *III.* *A*, section of *IV.* at *x—x*; *B*, section at *x—y*, the lettering as in *III.* *C*, section at *s—s*, the lettering as in *III.*—After Sachs.

it is curved entirely around the remainder of the embryo. Under proper conditions the main root pushes through the root sheath (*ws*, Figs. 331, 332). The plumule, consisting of a minute stem and a few rudimentary leaves, next pushes out through the upper end of the curved cotyledon (*II.*, Fig. 332). The cotyledon remains in contact with the endosperm and absorbs nourishment from it for the sustenance of the growing parts. Lateral roots soon appear upon the main root, and adventitious ones arise from the first internodes of the stem (w''', w'', w', Fig. 332). The first leaf above the cotyledon is quite small (*b*), and each succeeding one becomes larger and larger until the full size is reached.

In the Date the small embryo lies imbedded transversely in the large endosperm. In germination the cotyledon elongates and carries the enclosed root and plumule outside of the seed (*II.* and *III.*, Fig. 333). The apex of the cotyledon (*c*) expands into an organ through which the dissolving endosperm is absorbed. The root pushes downward, and soon develops lateral roots (w'). The plumule grows upward, escaping from the enclosing cotyledon, as shown in *IV.*, Fig. 333. The first leaves above the cotyledon are here, as in the Indian corn, much less perfectly developed than the later ones.

551.—The sub-class Monocotyledones contains about fifty natural orders of plants, which are grouped into fifteen cohorts. Of these only a few need be noticed.

552.—Cohort I. Glumales. Grass-like plants with the flowers in the axils of scales, which are arranged in spikelets; the stamens are from one to three, rarely more; the single ovary contains but one ovule, and these at maturity are completely coalesced, forming a caryopsis.

Order Gramineæ.—The Grass Family. Herbaceous or rarely woody plants, with round, jointed, and mostly hollow stems, bearing alternate two-ranked leaves with split sheaths. (Figs. 334–9.)

This very natural order contains about 4500 species, which are distributed in all climates. In the tropics they are large and almost tree-like (Bamboo); in the temperate climates they cover the ground with a close mat, while in the colder countries they grow in bunches. Very many of the species are valuable on account of their starchy seeds or nutritious herbage. None are poisonous (with possibly one or two exceptions).

Triticum vulgare, Wheat, a native probably of Southwestern Asia, has been under cultivation in temperate climates for several thousand years. Remains of wheat grains have been found in the ruins of the lake dwellings in Switzerland, proving that it was cultivated in Europe in prehistoric times. By long culture it has formed many varieties;

some of these are hardy (winter wheats), others are tender (spring wheats); some are awned, others awnless; in some the grains are

FIGS. 334–9.—INFLORESCENCE OF THE OAT.

FIG. 334.

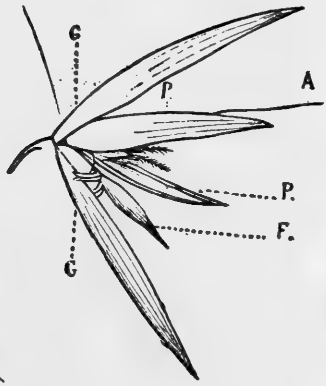


FIG. 335.

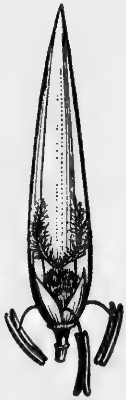


FIG. 336.

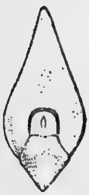


FIG. 337.

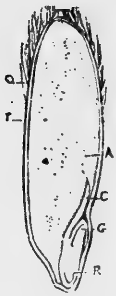


FIG. 338.

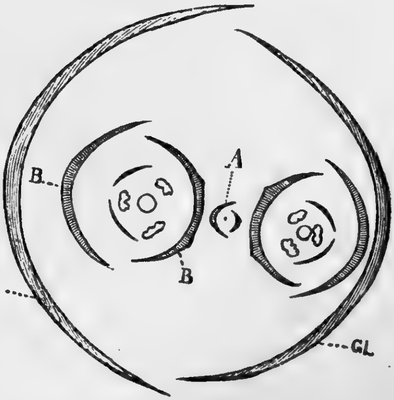


FIG. 339.

Fig. 334.—Spikelet.
Fig. 335.—Spikelet opened. *G*, glumes; *P*, palets; *A*, awn; *F*, abortive flower.
Fig, 336.—Flower with upper palet.
Fig. 337.—Embryo.
Fig. 338.—Section of grain.
Fig. 339.—Diagram of spikelet. *Gl*, glumes; *B*, palets; *A*, abortive flower.

dark in color (red wheats), in others they are light colored (white wheats). Fabre's experiments about a quarter of a century ago appear to indicate that wheat was originally derived from a wild grass called

Ægilops ovata. From it, in the course of from ten to twelve years, he succeeded in producing the form known as cultivated wheat. (See *Gardener's Chronicle*, July, 1852.)

Secale cereale, Rye, is probably a native of Southeastern Europe and Southwestern Asia. It has been cultivated for ages and is still much grown in temperate climates.

Hordeum vulgare, Barley. A native probably of the same region as Rye ; has also been long under cultivation. One or two other species are also grown.

Avena sativa, the Oat, was formerly much used as food for man, especially in cool climates, where it succeeds best. It is now less used. Its native country is not certainly known, but it was probably northern Europe or Asia.

Oryza sativa, Rice, has been long under culture in Southeastern Asia, of which country it was probably a native. It is now cultivated also in Egypt, Italy, Brazil, and the Southern United States. It furnishes food to more human beings than any other single plant.

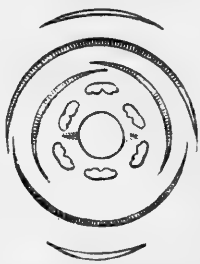


Fig. 340.—Diagram of hexandrous flower of Rice.

Zea Mais, Maize or Indian Corn, a native of the warmer parts of the New World, was cultivated by the aborigines of both North and South America before the advent of Europeans. It is one of the most valuable of the cereals, and is now cultivated almost all over the world. Of its numberless varieties the larger are grown in the hotter, and the smaller in the cooler climates.

The more important forage grasses are the following :

Phleum pratense, Timothy or Herd's Grass, a native of Europe is valuable on rich soils.

Agrostis vulgaris, Red-top, a native of Europe, grows well on moist soils.

Dactylis glomerata, Orchard Grass, a native of Europe, is valuable because of its growing well in the shade, and so furnishing hay and pasture in orchards and woodlands.

Poa pratensis, Kentucky Blue Grass, a native of the Eastern United States and of Europe, is in the latitude of Kentucky the best of all our pasture grasses. In drier regions it is small and harsh.

Muhlenbergia glomerata and *M. Mexicana* constitute the "Fine Slough Grass" of the Mississippi valley prairies. They furnish valuable hay.

Several species furnish sugar :

Saccharum officinarum, Sugar Cane, a native of the warmer parts of Asia, is a large plant somewhat resembling Indian corn in size and appearance. From its sweet juice most of the sugar and molasses of com-

merce are made. It is cultivated extensively in the Southern United States, Cuba, Brazil, and, in fact, in all warm countries of the world.

FIGS. 341-4.—ILLUSTRATIONS OF CAREX.

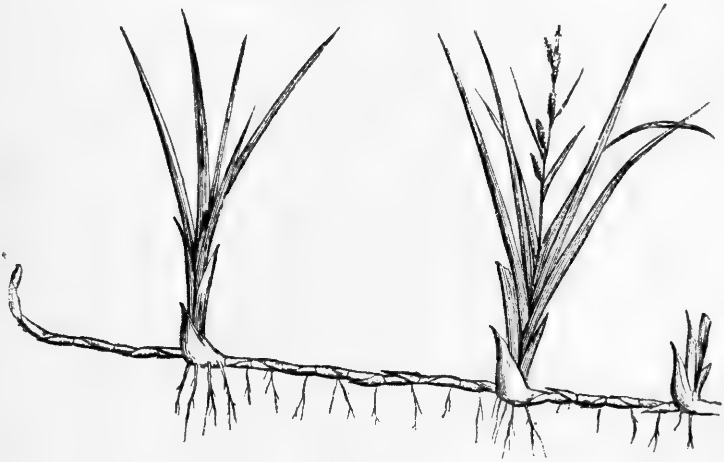


FIG. 341.

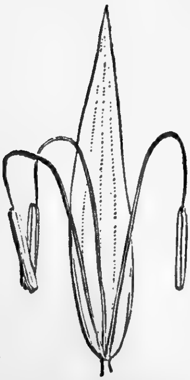


FIG. 342.

FIG. 343.

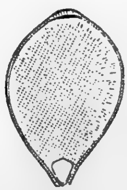


FIG. 344.

Fig. 341.—Underground stem, sending up leafy and flowering stems.
Fig. 342.—Male flower. Magnified.
Fig. 343.—Female flower. Magnified.
Fig. 344.—Section of seed. Magnified.

It is a curious fact that while the annual production of cane sugar in the world is now about 4,000,000,000 pounds, yet five hundred

years ago it was but little known to our European ancestors, and even a century and a half ago it was one of the luxuries. (Simmonds.)

Sorghum vulgare, Chinese Sugar Cane, a native of India, has within a few years been brought into cultivation in the United States for its sweet juice, from which molasses and sugar are made. One variety of this species is the Broom Corn, used in the manufacture of brooms.

Several species of Bamboo (*Bambusa*, sp.) growing in India become so large as to supply materials for building the houses of the natives.

B. arundinacea sometimes attains the height of 30 metres (100 ft.). Its uses are almost innumerable.

Order Cyperaceæ.—The Sedge Family. Herbaceous plants, with three-angled solid stems, bearing alternate three-ranked leaves, with entire sheaths. (Figs. 341–4.)

There are about two thousand species of sedges, which are distributed throughout the world. They grow in tufts, never forming a continuous mat, and generally prefer wet localities. They are of little value to man, and their stems contain so little nutritious matter that they are eaten only to a limited extent by animals.

Cyperus esculentus, the Chufa, a native of the Mediterranean region, is somewhat cultivated for its small, sweet-tasting tubers.

Cyperus textilis is used in India for making ropes and mats; in Egypt other species are used for the same purpose.

Papyrus antiquorum, Papyrus, is a tall growing plant with stems 2–3 cm. (1 inch) in diameter. It is a native of Egypt and the adjacent countries, and from it the inhabitants anciently made paper by slicing its cellular pith, and afterward hammering and smoothing it.

553. Cohort II. Restiales.—This includes three orders of mostly tropical plants bearing glumaceous flowers.

Orders Restiaceæ, Eriocaulonaceæ, and **Flagellarieæ.**

554. Cohort III. Commelynales.—Plants with a hexamerous perianth, in two whorls, the inner colored and petaloid.

Orders Mayaceæ, Xyridaceæ, and **Commelynaceæ.**
The latter contains the well-known Spiderwort *Tradescantia*, sp.).

555. Cohort IV. Pontederales.—Marsh plants with a gamophyllous petaloid perianth.

Orders Philydreæ, Pontederiaceæ, and **Rapateæ.**

556. Cohort V. Liliales.—Plants with a hexamerous (rarely tetramerous) perianth, the parts united or free, and usually petaloid.

Order Juncaceæ.—The Rushes. Natives of temperate and cold

climates. The leaves and stems are woven into matting and chair bottoms, and the pith is used for the wicks of candles (rush-lights).

Order Liliaceæ.—The Lily Family. Perennial, mostly herbaceous plants, with entire leaves, and generally showy flowers. The species, of which there are about two thousand, are distributed in all climates. Some of these are valuable as food, others furnish useful medicines, while many are among our finest ornamental plants.

The more important food plants are the following:

Allium Cepa, the Onion, a native probably of the Mediterranean region, is grown throughout the world.

Allium Porrum, the Leek, *A. sativum,* Garlic, *A. ascalonicum,*

FIGS. 345-8.—ILLUSTRATIONS OF FRITILLARIA.

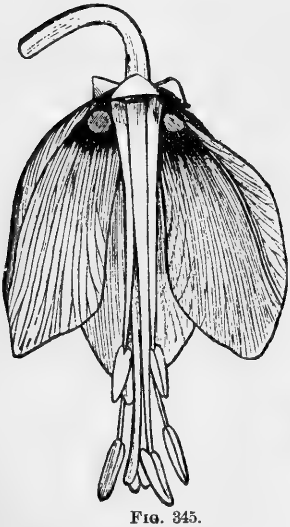


FIG. 345.

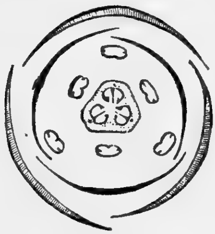


FIG. 346.

FIG. 347.

FIG. 348.

Fig. 345.—Section of flower.
Fig. 346.—Flower diagram.
Fig. 347.—Section of ovary.
Fig. 348.—Ovule.

Shallot, and a few other species, all natives of the Old World, are considerably used.

Asparagus officinalis, Asparagus, is a native of the Atlantic and Mediterranean coasts of Europe, and of the sandy plains of Central and Western Asia. It has been cultivated in England for upwards of two thousand years, but it is an interesting fact that in all that time it has exhibited very little variation.

Among the medicinal plants may be mentioned

Aloe vulgaris, of the Mediterranean region, and other species in

Southern and Eastern Africa, the inspissated juice of whose leaves constitutes the drug Aloes.

Smilax officinalis, of South America, and other species, furnish Sarsaparilla root.

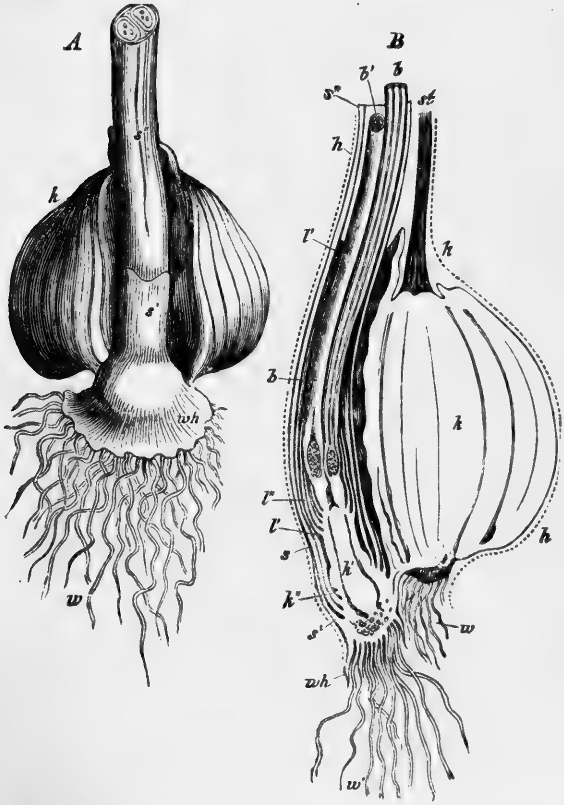


Fig. 349.—Underground parts of *Colchicum autumnale* at the time of flowering. *A*, front view ; *k*, old corm ; *s'*, *s''*, scales surrounding flower stalk. *B*, section showing new stem, *k'*, with rudimentary leaves. *l'*, *l''* ; the very long tubular flowers, *b*, *b'*, spring from near the summit of the new stem, *k'*. The following spring *k'* will elongate and carry the fruit, and leaves *l'*, *l''*, above ground ; the lower part of *k'* will enlarge into a corm like *k'*, while at *k''* a new plant will form as a lateral bud.—After Sachs.

Scilla maritima ; the sliced bulb of this Mediterranean sand plant is the drug Squill.

Veratrum album, the White Hellebore of the mountains of Central

Europe, and *V. viride*, Green Hellebore of the Eastern United States, are poisonous emetics. The rhizome is officinal.

Ornamental plants:

Asphodelus luteus is the Asphodel of Southern Europe.

Agapanthus umbellatus, the Love Flower of the Cape of Good Hope, is a beautiful green-house plant, bearing pale blue flowers.

Colchicum autumnale, the "Meadow Saffron" or "Autumn Crocus" of Europe, is curious for its producing leaves in the spring, and then, long after these have died down, in the autumn sending up one or two long-tubed pale flowers, which soon wither away; the following spring, by the lengthening of the underground stem, the seed-pod is carried up, along with the green leaves (Fig. 349). The corms of this plant were formerly in some repute as medicines.

Convallaria majalis, the Lily of the Valley, is a native of woodlands and shady places in England, Europe, and Siberia.

Dracæna Draco, the Dragon Tree of Western Africa and the adjacent islands, is cultivated as a curiosity in green-houses. A tree of this species on the island of Teneriffe was, at the time of its destruction by a hurricane in 1867, upwards of 20 metres (70 ft.) high, and 5 metres (16 ft.) in diameter, and from its known slow growth it must have been many hundreds, possibly some thousands, of years old.

Fritillaria imperialis, the Crown Imperial, a native of the south of Europe and Western Asia, is a showy plant.

Funkia, sp., and *Hemerocallis*, sp., the Day Lilies, the former from China and Japan, the latter from Southern Europe, and *Hyacinthus orientalis*, the Hyacinth of Asia Minor, are in common cultivation.

Lilium—many species. The True Lilies. Aside from our native species, *L. Philadelphicum*, *L. Canadense*, and *L. superbum*, which deserve cultivation, the following are commonly found in gardens:

- *L. bulbiferum*, the Orange Lily, from Southern Europe; flowers orange.
- *L. tigrinum*, the Tiger Lily, from China; flowers orange-red.
- *L. Pomponium*, the Turban Lily, from Europe; flowers red.
- *L. Chalcedonicum*, the Red Lily, from Asia Minor; flowers red.
- *L. Martagon*, the Turk's Cap Lily, from Europe; flowers flesh-colored.
- *L. speciosum*, the Showy Lily, from Japan; flowers rose-colored.
- *L. auratum*, the Golden Lily, from Japan; flowers white and golden.
- *L. candidum*. the White Lily, from Asia Minor; flowers white.
- *L. Japonicum*, the Japan Lily, from Japan; flowers white.
- *L. longiflorum*, the Long-flowered Lily, from Japan; flowers white.

Myrsiphyllum asparagoides, a delicate climber from the Cape of Good Hope, is grown in windows and conservatories under the name of Smilax.

Ornithogalum umbellatum, the Star of Bethlehem, is a native of Central Europe.

Polianthes tuberosa, the Tuberose, a native probably of the East Indies, bears a tall spike of fragrant white flowers. It is sometimes placed in the order Amaryllidaceæ.

Ruscus aculeatus, the Butcher's Broom of England and Southern Europe, a curious shrub, with flat leaf-like branches, is rarely cultivated with us.

Tritoma uvaria, of the Cape of Good Hope, bears a tall spike of red flowers, and hence receives in cultivation the name of the "Red-Hot Poker Plant."

Tulipa Gesneriana, the Tulip, is a native of the Levant. It was brought into Europe about three hundred years ago, and originally bore yellow flowers, but under long culture it has developed numberless varieties. To the Dutch we owe much of the improvement in this flower ; in the first half of the seventeenth century throughout Holland so much attention was given to its culture, and such high prices paid for single bulbs of the finer varieties, that a speculative mania (known as the "tulipomania") arose, resembling the wildest of modern grain or stock manias.

Yucca, of several species, known by the name of Adam's Needle, Spanish Bayonet, Bear Grass, etc., is a genus of fine ornamental plants, natives of the warmer parts of America. The strong fibres are sometimes made into cordage. The roots contain *saponin*, and are used by the Mexicans instead of soap for washing.

Xanthorrhœa includes the curious Grass Gum Trees of Australia.

557.—Cohort VI. Arales.—A group of dissimilar plants, some being large trees, and others microscopic floating herbs.

Order Lemnaceæ.—The Duckweeds. These smallest of Phanerogams consist of floating disks (thalli), with no distinction of leaf and stem, bearing one or several roots beneath (in *Wolffia*, however, no roots). They are parenchymatous throughout, or with only rudimentary vascular tissues. Their flower-clusters are sunken into pits in the top or edge of the disks, and consist of one or two stamens and a single pistil, representing as many reduced flowers. There are about twenty species, widely distributed throughout the northern hemisphere. We have eight or ten species in the United States. (Figs. 350–2.)

Order Aroideæ.—The Arum Family. Herbs often large and palm-like in appearance, with large leaves having reticulated venation. Inflorescence generally surrounded by a spathe. Of the Aroids there are about 1000 species, distributed mostly in tropical countries, where they sometimes attain a height of several metres (6–12 feet); in temperate climates they are much smaller. They possess an acrid juice, which may be poisonous.

Some of the species have been used in medicine, among which are the Indian Turnip (*Arisœma*), and Sweet Flag (*Acorus*).

Calocasia antiquorum, a large plant of the tropics, is there grown for its fleshy farinaceous corm. It is grown with us for its fine foliage.

Richardia Africana, the so-called Calla-lily, or Ethiopian Lily, a native of the Cape of Good Hope, is a common green-house plant.

Symplocarpus fœtidus, the Skunk-cabbage of the Northern United States, is remarkable for the mephitic odor of its bruised leaves.

Amorphophallus Titanum, an Aroid discovered in 1878 by Beccari in

FIGS. 350-2.—ILLUSTRATIONS OF LEMNA.

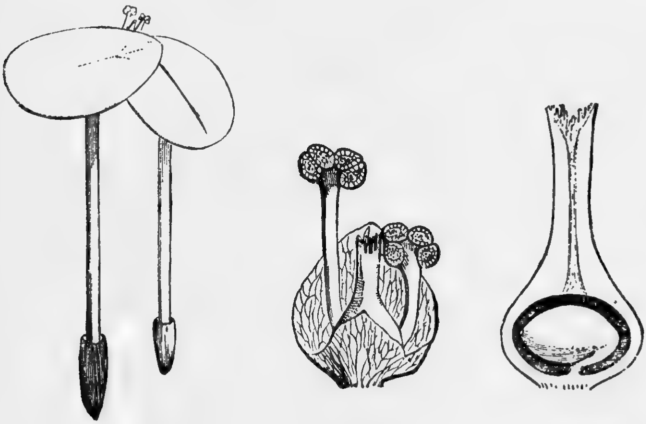


FIG. 350. FIG. 351. FIG. 352.

Fig. 350.—Two plants of *L. minor*. Magnified.
Fig. 351.—Three flowers in a spathe.
Fig. 352.—Section of pistil.

Sumatra, has an enormous spathe, 1.7 metres (6 feet) in depth, and 83 cm. (2⅔ feet) in diameter.

Order Typhaceæ, represented by the two genera *Typha* and *Sparganium*.

Order Pandanaceæ.—Mostly tropical plants, some of them of a tree-like aspect.

Pandanus includes the Screw Pines of the East Indies, so called from the spiral arrangement of their clustered leaves.

Carludovica palmata, a Central American plant, with palmate radical leaves borne on petioles three metres (8–10 feet) long, is important as furnishing the material from which the famous Panama hats are made.

558.—Cohort VII. Palmales.—Shrubs or trees with divided (rarely simple) leaves. Flowers in a spadix.

Orders Nipaceæ and Phytelephasieæ, both of the tropics. In the latter, *Phytelephas macrocarpa,* of Central America, is remarkable for the ivory-like endosperm in its large seeds ; hence its name of Ivory Nut.

Order Palmaceæ.—The Palm Family. Trees, shrubs, or woody climbers ; natives almost exclusively of the torrid zone, or the adjacent

FIGS. 353–6.—ILLUSTRATIONS OF PALMACEÆ.

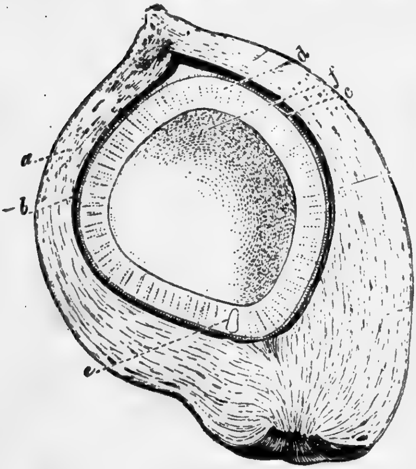


FIG. 353.

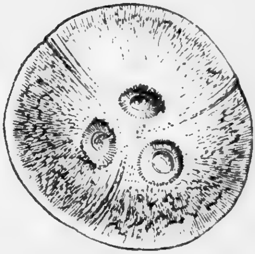


FIG. 354.

FIG. 356.

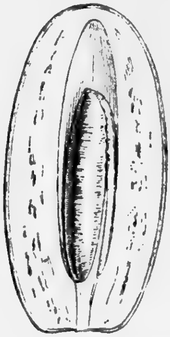


FIG. 355.

Fig. 353.—Fruit of Cocoa-nut. *a*, exocarp ; *b*, endocarp ; *c*, testa ; *d*, endosperm ; *e*, embryo ; *f*, milk cavity.
Fig. 354.—Cocoa-nut seen from below.
Fig. 355.—Vertical section of a Date, showing seed inside.
Fig. 356.—Seed of Date in cross-section, showing embryo.

hotter portions of the temperate zones, being rarely found beyond 40° North and 35° South latitude. The arborescent species are among the most striking and majestic of plants ; their long cylindrical stems frequently rise to the height of thirty metres (100 feet), bearing at their summits spreading crowns of large leaves, and drooping clusters of fruit. The whole number of known species is not far from one thousand.

The economic value of the Palms is very great ; in fact it may be ques-

tioned whether any other order of plants (the Grasses possibly excepted) approaches them in the importance of the products they furnish. Every species appears to be useful, and the uses of some of the species may be reckoned by hundreds. In some countries every want of man is supplied by one or another of the palms.

I. Tribe Cocoineæ.—*Atalea funifera* is a Brazilian species of stout-growing trees, whose fibrous leaves are used in making ropes, mats, and coarse brooms. The nuts, known as Coquilla nuts, are seven to eight cm. (3 inches) long, very hard, and are used for making door-handles, bell-pulls, etc.

Cocos nucifera, the Cocoa-nut Palm, is a native of the coasts of tropical Africa, India, Malay, and islands of the Indian and Pacific Oceans. It is now, however, cultivated throughout the tropics. The tree varies in height from fifteen to thirty metres (50 to 100 feet), and bears long pinnate leaves. The nuts, which are borne in clusters of seven to ten or more, are the well-known cocoa-nuts of commerce. As a new cluster is pushed out every month, the annual yield of a single tree may be from 100 to 150 or more nuts, and this may continue for forty years. In some parts of India and other countries, the white albumen of the nut forms nearly the entire food of the natives, and the milk serves them for drink. In this country great quantities are used as a delicacy and for culinary purposes.

In cocoa-nut countries the uses of the root, stem, leaves, and fruit are said to be as numerous as the days in the year, sufficing for all the wants of the inhabitants. The root is used as a masticatory; the stem is used for the most diverse purposes, while the hard case of the base is used for making drums, and in the construction of huts, the tender terminal bud is highly prized as an article of food. The juice of the flower-stems is rich in sugar, and this, by fermentation, produces an excellent wine, and by distillation yields a spirit called arrack. From the sheaths and leaves the natives construct roofs, fences, baskets, buckets, ropes, mats, brooms, and numerous other articles. The fibre from the leaves and sheaths is imported into this country and made into "coir" ropes, floor-matting, brushes, and brooms, and used also for stuffing cushions. Even the hard shell is of use in the manufacture of cups and ornaments.

Elæis guineensis, of West Africa, produces annually large quantities of pulpy fruits, each containing a hard nut. From these palm oil is obtained, which is used in Europe and the United States for making candles, for the manufacture of soap, and also to some extent for lubricating purposes.

II. Tribe Coryphineæ.—*Copernica cerifera*, the Wax Palm of Brazil, attains the height of twelve metres (40 feet), with a diameter of stem of thirty cm. (1 foot). The hard wood takes a fine polish, and is used for veneering. The young leaves are coated with a waxy secretion which is used in England for making candles.

Phœnix dactylifera, the Date Palm, is a native of Northern Africa and Western Asia, now naturalized in the south of Europe. The tree is diœcious, and grows to the height of ten to twelve metres (40–50 feet), bearing a crown of leaves, each leaf being four to six metres (15–20 feet) long. The fruit is produced in large bunches, containing from twenty to thirty dates. Dates constitute a large portion of the food of the Arabs of the African and Arabian deserts. They are largely imported into the United States. They are prepared by gathering before they are quite ripe, and then drying in the sun.

The cultivation of the date palm has for ages been an object of first importance in Arabia and Northern Africa. The trees are hereditary, and are sold as estates, constituting the chief wealth of the inhabitants.

Sabal Palmetto, the Cabbage Palmetto, *S. serrulata*, the Saw Palmetto, *S. Adansonii*, the Dwarf Palmetto, and *Chamærops Hystrix*, the Blue Palmetto, all of the southeastern United States, and *Washingtonia filifera*, of California and Arizona, are our principal native palms.

III. Tribe Borassineæ.—*Borassus flabelliformis*, the Palmyra Palm, is a native of nearly all Southern Asia. It has large fan-shaped leaves, anda cylindrical stem rising to the height of fifteen to thirty metres (50 100 feet). Wine, or toddy, and sugar are made from the juice; the young sprouts of the flowering branches are used for food in the same manner as asparagus. From the stem is obtained Palmyra wood.

Hyphæne thebaica, the Doum or Gingerbread Palm, is a branching species of the upper Nile region. It produces fruits of the size of an apple and with the flavor of gingerbread. A resin derived from this tree is known as Egyptian Bdellium.

Lodoicea sechellarum, the Double Cocoa-nut of the Seychelle Islands in the Indian Ocean, is a giant among the palms. It attains the height of thirty metres (100 feet), its stem being forty-five to sixty cm. (1½ to 2 feet) in diameter. It produces large oblong nuts, which have the appearance of being double, and which weigh from thirty to forty pounds. They are borne in bunches of nine or ten in number, so that a whole bunch will often weigh 400 pounds. It takes ten years to ripen the fruit, the albumen of which is similar to that of the common cocoa-nut, but it is too hard and horny to serve as food. The leaves are made into hats, baskets, etc. The demand for the leaves for these uses has become so great that the trees are cut down in order to obtain them, and as no care is taken to form new plantations, it is feared that this palm will eventually become extinct.

IV. Tribe Calameæ.—*Calamus Rotang* and several other species include the Rattan or Cane Palms of India and the Malayan Islands. They have slender reed-like stems which grow to a great length, often from sixty to one hundred or more metres (200–300 feet), and are imported into Europe and the United States for making chair-bottoms, umbrella-ribs, etc.

Calamus Draco, of the same region as the preceding, yields a reddish resinous substance known as Dragon's Blood, and which is a secretion coating the surface of the small fruits. Dragon's blood is used for coloring varnishes and for staining horn.

Sagus lævis and *S. Rumphii*, Sago Palms, are trees nine to fifteen metres (30–50 feet) high, natives of Siam, the Indian Archipelago and other islands of the East. The sago is obtained by splitting the trunks and extracting the soft white pith ; this is thrown into tanks of water, in which it is repeatedly washed and strained until a pure pulpy paste is obtained. In this state, in order to preserve it, the natives keep it under water, and it forms a large proportion of their food. For exportation it is dried and granulated through sieves. A tree fifteen years of age yields from six to eight hundred pounds of this nutritious material.

V. Tribe Arecineæ.—*Areca Catechu,* the Betel Palm of Cochin China and the Malayan peninsula and islands, produces a fruit of the size of a hen's egg, which is the famous Betel Nut or Pinang of the far East. The nut is cut into pieces and rolled up with lime, gambier, etc., in a leaf of the betel pepper, and chewed as tobacco is in this country.

Caryota urens, of India, is one of the wine or "Toddy" palms. It grows to the height of fifteen to eighteen metres (50–60 feet), and has a large crown of compound winged leaves. It is said that this tree will yield one hundred pints of toddy in twenty-four hours.

Ceroxylon andicola, the Wax Palm of the mountains of New Granada, is a tall tree, bearing large pinnate leaves five to six metres (15–20 feet) long. It is found on the mountain sides nearly to the snow line. The trunk is coated with a resinous wax, which is scraped off by the natives and used for making candles.

Chamædorea of several species, climbing palms of New Granada are interesting on account of their stems being used in forming suspension bridges.

Saguerus saccharifer of the Malayan Archipelago is a valuable Sago Palm. It is twelve to fifteen metres (40–50 feet) high, and bears enormous pinnate leaves ; a tree grown in the Kew Gardens bore leaves twelve metres (40 feet) in length. Sugar is also obtained from the juice which flows from the wounded spadix.

559. Cohort VIII. Potamales.—Mostly herbaceous water plants, with all of the parts of the flower distinct ; the embryo large, and endosperm wanting.

Order Naiadaceæ.—The Pond-weeds.

Order Alismaceæ.—The Water Plantain Family. This order is interesting from the fact of its evident relationship to the Ranales (Cohort 36) among Dicotyledons, as long ago suggested by Adanson, and insisted upon by Lindley. (Figs. 357–9.)

Alisma and *Sagittaria* are two common genera.

560. Cohort IX. Triurales, with one small and little known order.

Order Triurideæ.—Delicate, almost colorless herbs of the tropics.

561. Cohort X. Dioscorales.—Climbing herbs or undershrubs, bearing reticulately veined leaves.

Order Dioscoreaceæ.—The Yam Family. Several species of *Dioscorea* produce edible tubers.

D. sativa, D. aculeata, and other species of India are extensively grown there and in the West Indies as potatoes are grown in cooler climates.

D. Batatas and *D. Japonica* are known as Chinese Yams.

Testudinaria elephantipes, of the Cape of Good Hope, is a curious

FIGS. 357-9.—ILLUSTRATIONS OF ALISMA PLANTAGO.

FIG. 357.

FIG. 358.

FIG. 359.

Fig. 357.—Flower cut vertically. Magnified.
Fig. 358.—Seed. Magnified.
Fig. 359.—Section of seed. Magnified.

green-house plant, having a large, woody, above-ground corm-stem, from which spring every year slender twining stems.

562. Cohort XI. Narcissales.—Plants with narrow, often equitant leaves, having parallel venation; seeds containing endosperm.

Order Hæmodoraceæ.—The Blood-wort Family.

Order Amaryllidaceæ.—The Amaryllis Family. Distinguished from the next order by having six stamens, and leaves which are not equitant. The four hundred species are herbs of temperate and tropical climates; many possess a narcotic and poisonous principle.

Agave Americana, the Century Plant of Mexico, is now much grown in conservatories, and is said to be naturalized in Southern Europe. In California and its native country it blooms at the age of from ten to

fifteen years, but in cool climates it requires from thirty to seventy or more. The mature plant has a cluster of thick, sharp-pointed radical leaves, each about 2 metres (6 ft.) long, from the centre of which it sends up a flowering stem 10–15 cm. (4–6 in.) thick, and 5–6 metres (16–20 ft.) high, bearing hundreds of yellow flowers. The Mexicans cut out the central bud just before the lengthening of the flowering stem, and from the juice, which flows out in great abundance, obtain by fermentation the drink called "Pulque," or by distillation the more generally used "Mescal." The subterranean stems possess a detergent principle, and under the name of "Amole" are much used by the Mexicans in washing. The strong fibres in the leaves are used for cordage.

Hæmanthus toxicaria, of South Africa, has a poisonous bulb, which is used by the Hottentots for poisoning their arrows.

Many species are grown for the beauty of their flowers; among these may be mentioned:

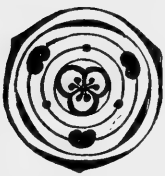


Fig. 360. — Flower diagram of Iridaceæ.—After Sachs.

Amaryllis, of many species, mostly from South Africa and South America.

Galanthus nivalis, the Snowdrop, of Europe.

Leucojum vernum, the Snowflake, of Europe.

Narcissus, of many species; this includes the Daffodil, Jonquil, Polyanthus, etc., all natives of Europe.

Order Iridaceae.—The Iris Family. The stamens are only three (by the abortion of an inner whorl, Fig. 360), and the leaves are equitant. The order contains five hundred species, which are mainly found in the south temperate climates, a smaller number occurring in north temperate regions. They contain a purgative principle, which has been used in medicine.

Crocus vernus and other species are commonly grown for their early spring flowers; the dried stigmas of *C. sativus* constitute the drug Crocus or Saffron used in medicine and also in dyeing.

Gladiolus psittacinus and other species, from the Cape of Good Hope, are deservedly popular as ornamental plants.

Iris Germanica, of Europe, and many other Old World species, are common in gardens.

Our native *I. versicolor, I. cristata*, and others, are also worthy of culture.

563. Cohort XII. Taccades.—This includes two small tropical orders of herbaceous plants.

Orders Taccaceæ and **Burmanniaceæ.**

564. Cohort XIII. Orchidales.—Herbs with a hexamerous (rarely trimerous) zygomorphic perianth; the stamens and style more or less confluent into a common column, and

the minute seeds containing a rudimentary embryo and no endosperm.

Order Apostasiaceæ, a small order of East Indian plants, which are interesting because of their evident relationship to the Orchids, from which they differ in having the style partially free from the stamens.

Order Orchidaceæ. — The Orchids. Terrestrial or epiphytic plants, whose stamens and style are completely united into a common column or *gynostemium.* The three thousand species are found in "all climates and in all situations but maritime and aquatic." (Hooker.)

This order has long been highly esteemed for the many curiously shaped and colored flowers it affords, and many hundreds of its species are to be found in cultivation in conservatories. They are interesting also from the fact that none of them are, unaided, capable of fertilizing their ovules, and appear in every case to be dependent upon insects for the transport of the pollen and its deposition upon the stigma.

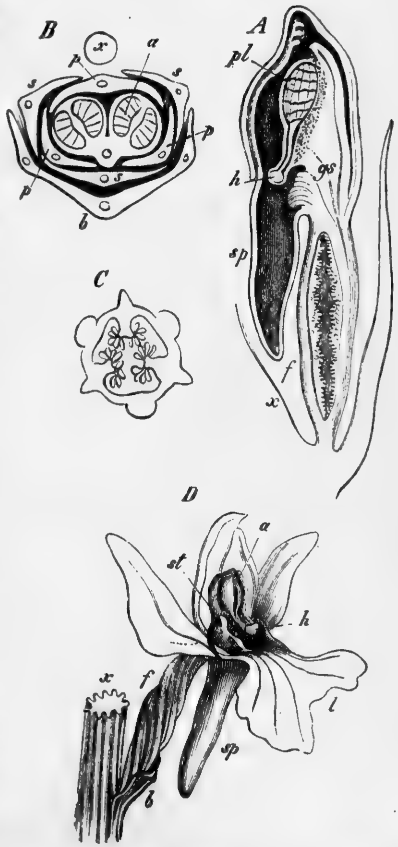


Fig. 361.—*Orchis maculata.* *A*, a symmetrical vertical section of a flower bud. *B*, transverse section of the bud. *C*, transverse section of ovary. *D*, mature flower, with one sepal removed; *x*, axis of flower cluster; *b*, bract; *s*, sepals; *p*, petals; *l*, labellum; *sp*, its spur; *a* and *pl*, pollen-mass; *h*, its viscid disc; *gs*, the column (gynostemium); near *gs* is the stigma which projects toward *h*; *f*, inferior ovary, twisted in *D*; *st*, staminodes.—After Sachs.

This great order is usually divided into seven tribes, as under.

Tribe I. Cypripedieæ, with two polliniferous stamens containing granular pollen (Fig. 362).

In this the genus *Cypripedium,* which contains our native Lady's-Slippers, is the most important. Some of the species, notably *C. spectabile* and *C. acaule,* are greatly admired in cultivation.

Tribe II. Neottieæ, with a single dorsal anther, containing two or four soft pollen masses attached to a viscid disc. Our principal genus is *Spiranthes.*

Tribe III. Arethuseæ, with a single terminal anther, containing two or four powdery pollen masses.

Our native *Arethusa* and *Calopogon* are fine representatives of this tribe. The Vanilla plant (*Vanilla planifolia,* and other species) of tropical America, a climbing epiphyte, produces fleshy capsules 12 to 25 cm. (5–10 in.) long, which are highly aromatic, and much used in the manufacture of confections, beverages, medicines, etc. When first introduced into the East Indies, where it is now much grown, it failed to perfect fruit; artificial p llination having been resorted to, however, the difficulty at once disappeared. (Fig. 363.)

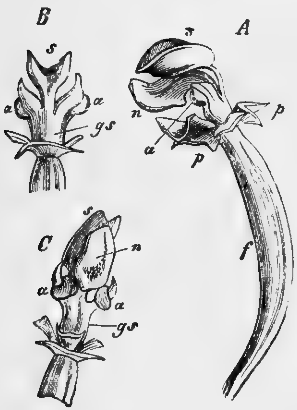


Fig. 362. — Sexual organs of the flower of *Cypripedium calceolus,* the perianth, *p,* removed. *A,* side view. *B,* back view. *C,* front view. *f,* the inferior ovary; *gs,* the column or gynostemium; *aa,* stamens; *s,* sterile stamen or staminode; *n,* stigma.—After Sachs.

Tribe IV. Ophrydeæ, with a single anterior anther, containing two stalked pollen masses, each attached to a viscid disc (Fig. 361).

Our pretty little *Orchis spectabilis,* and many species of *Habenaria,* are our principal representatives of this tribe. From the tubers of *Orchis mascula* and other European and Asiatic species, the starchy-mucilaginous and highly nutritious substance "Salep," is obtained.

Tribe V. Vandeæ, with a single terminal or dorsal anther, containing waxy pollen masses attached to a viscid disc.

We have no native representatives of this tribe. Many of the tropical species are of wonderful forms; indeed, as Mr. Darwin says of them, they are "the most remarkable of all Orchids." In some genera they assume the most curious forms, resembling insects of various kinds, birds, etc., etc. In *Catasetum saccatum,* a diclinous South American species, when certain sensitive parts of the column of the male flower are touched by an insect, the pollen masses are by a peculiar contrivance thrown out forcibly in such a direction as to strike the insect, to which it adheres by a viscid disc, and is thus carried to and brought in contact with the stigma of the female flower.

Tribe VI. Epidendreæ, with a single terminal anther, containing stalked, waxy pollen masses, these not attached to a viscid disc. To this tribe belong in the United States *Tipularia, Bletia,* and *Epidendrum,* the latter an epiphyte, occurring only in the Southern States.

Of the exotics, *Cœlogyne, Lælia, Cattleya,* etc., are to be seen in conservatories.

Fig. 363.—Ripened ovary of Vanilla, split open and showing the seeds.

Tribe VII. Malaxideæ, with a single dorsal, terminal, or anterior anther, which contains four stalkless, waxy pollen masses, not provided with a viscid disc.

Calypso, Liparis, Corallorhiza, and other genera occur in the United States; the last named appears to be parasitic. Among the many exotics may be mentioned *Bulbophyllum, Dendrobium, Malaxis,* etc.

565. Cohort XIV. Amomales.—Herbs (some almost arborescent) with hexamerous and mostly zygomorphic perianth; stamens six, generally from one to five only polliniferous.

Fig. 364. — Spike of the fruits of the Pine-apple (*Ananassa sativa*) terminated by a tuft of leaves.

Order Bromeliaceæ.—The Pine-apple Family. Distinguished from the next by the regular flowers and six perfect stamens. About two hundred species of almost entirely tropical plants constitute this order. But one genus (*Tillandsia*) is represented in the Southern United States; of the eight or ten native species, the Long Moss (*T. usneoides*) of the Southern Atlantic coast is the best known. It is used in upholstery and in the manufacture of mattresses.

Ananassa sativa, the Pine-apple, supposed to be a native of Brazil, is now cultivated throughout the world. In cool climates it is grown in hot-houses, and it is said that these are much better than those grown out of doors in warm climates. The fleshy fruits are aggregated into solid cone-like masses (Fig. 364), the well-known Pine-apples of commerce.

Order Scitamineæ.—The Banana Family, with zygomorphic perianth, and one to five, very rarely six, perfect stamens. Three sub-orders are well marked.

Sub-Order Musæ, with five polliniferous stamens (rarely six).

The genus *Musa* contains several exceedingly valuable plants. *M. sapientum*, the Banana, and *M. paradisiaca*, the Plantain, of the tropics everywhere, are large herbs, 3–5 metres (10–15 ft.) high, with the sheathing petioles of their large leaves forming a tree-like stem. Their well-known fruits constitute almost the sole article of food for millions of people in the tropics, and are also largely exported to all countries. It has been calculated that from twenty-five to sixty-six tons of bananas can be grown upon an acre of ground, supplying more nourishment to man than is afforded by any other plant. They are considerably grown in hot-houses, both as ornaments and for their

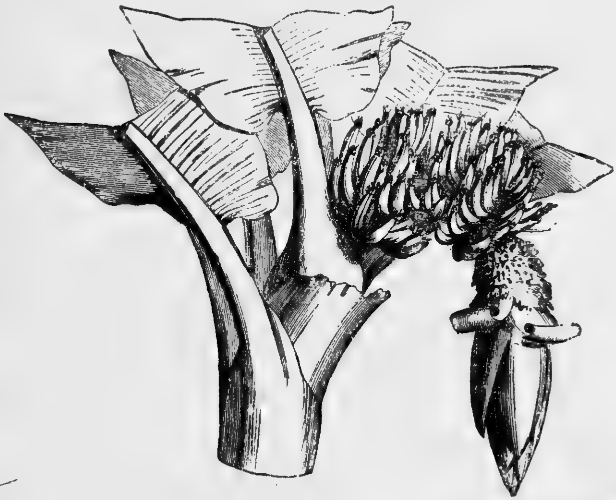


Fig. 365.—Part of a flowering plant of the Banana, showing the unfolding flower-bud and the young fruits.

fruits. From their leaves and petioles a good fibre is obtained, and from the allied *M. textilis* of the East Indies is obtained "Manilla Hemp," so much used in the manufacture of various textile fabrics.

Strelitzia Reginæ, of the Cape of Good Hope, is a common conservatory plant.

Sub-Order Zingiberæ, with one polliniferous stamen, bearing a two-celled anther. Several of these tropical plants are important.

Curcuma longa, of the East Indies and tropical Pacific islands, has a yellow colored rhizome, which constitutes the well known dye, "Turmeric."

Zingiber officinale, the Ginger Plant, probably a native of India, is now grown in most tropical countries for its aromatic rhizomes, which

when dried and powdered constitute the ginger of commerce. That from the West Indies, called Jamaica Ginger, is considered the best.

Sub-Order Cannæ, with one polliniferous stamen, bearing a one-celled anther. Aside from *Canna*, with its many ornamental species now common in gardens, one other plant deserves mention, viz.:

Maranta arundinacea, a native of tropical America, now grown extensively for its fleshy rhizomes, from which a starch known as "Arrowroot" is obtained.

566. Cohort XV. Hydrales.—Small aquatic plants, with a hexamerous regular perianth, and stamens three, six, nine, or twelve.

Order Hydrocharideæ.—This contains the Eel Grass, *Vallisneria spiralis*, and Water Weed, *Anacharis Canadensis*, common in our ponds; the latter is naturalized in England, where it chokes up streams.

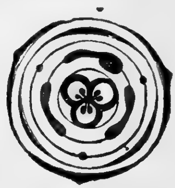


Fig. 366.—Diagram of the flower of *Canna*, showing theoretical structure. — After Sachs.

Fossil Monocotyledons.—The earliest Monocotyledon, so far as known at present, was a Triassic species of *Yuccites*, doubtfully referred to the Liliaceæ. In the Jurassic the Gramineæ, Cyperaceæ, Liliaceæ, Naiadaceæ, and Pandanaceæ were represented by a few species. In the Cretaceous the Cannæ, Dioscoreaceæ, and Palmaceæ appeared. A species of the last-named order has been discovered in the Cretaceous of Western Kansas. In the Tertiary most of the modern orders of Monocotyledons were represented (however, no orders of Cohorts II., III., and XIII. have yet been found). Fifteen species of palms have been described from the Tertiary of the Great Plains and the Rocky Mountain region,* extending as far north as northern Dakota and Vancouver's Island. Their remains are also abundant in the Tertiary of Mississippi.

SUB-CLASS II. DICOTYLEDONES.

(*Exogenæ* of De Candolle.†)

567.—In the plants of this sub-class the first leaves of the embryo are two and opposite, hence they are said to have two cotyledons. The venation of the leaves is for the most

---

* "Contributions to the Fossil Flora of the Western Territories. Part II. The Tertiary Flora," by Leo Lesquereux. Washington, 1878.

† From the Greek ἔξω, outside, and γένειν, to bring forth. The name is no longer a proper one, as we now know that these plants are not, strictly speaking, "outside growers;" on the contrary, they increase in thickness by the growth of an *internal* meristem layer.

part such that the veins rarely are parallel to each other, and in their anastomosing they form an irregular net-work.

The germination of Dicotyledons may be illustrated by a couple of examples. In the seed of the Windsor Bean (Fig. 367) the embryo entirely fills up the seed-cavity, the endosperm having all been ab-

FIGS. 367–8.—GERMINATION OF DICOTYLEDONS.

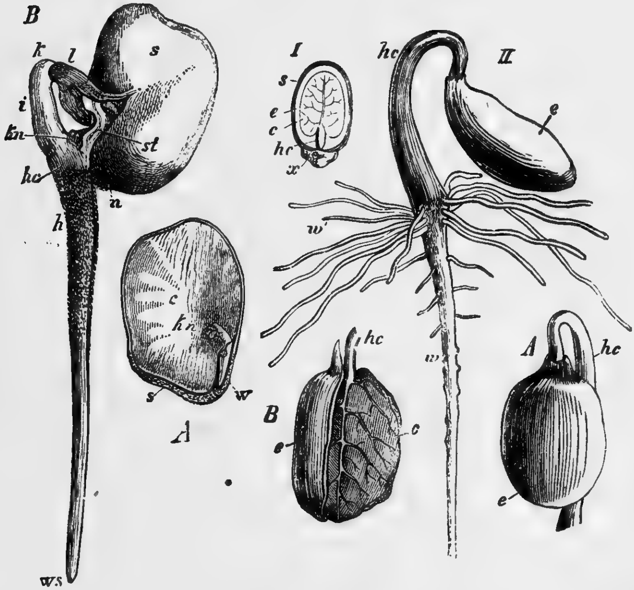


FIG. 367. FIG. 368.

Fig. 367.—*Vicia faba*. *A*, seed with one cotyledon removed; *c*, remaining cotyledon; *kn*, the plumule *w*, the radicle; *s*, seed-coat. *B*. germinating seed; *s*, seed-coat, partly torn away at *l*; *n*, the hilum; *st*, petiole of one of the cotyledons; *k*, curved epicotyledonary stem; *hc*, short hypocotyledonary stem; *h*, main root; *ws*, its apex; *kn*, bud in the axil of one of the cotyledons.—After Sachs.

Fig. 368.—*Ricinus communis*. *I.*, longitudinal section of the ripe seed. *II.*, germinating seed with the cotyledons still inside of the seed-coat (shown more distinctly in *A* and *B*). *s*, seed-coat; *e*, endosperm; *c*, cotyledon; *hc*. hypocotyledonary stem; *w*, primary root; *w'*, branches of root; *x*, caruncle, a peculiar appendage to the seeds of *Euphorbiaceæ*.—After Sachs.

sorbed. The thick cotyledons lie face to face, and are attached below to the small stem of the embryo plant. The stem extends upward a short distance between the cotyledons, bearing a few rudimentary leaves and itself ending in a *punctum vegetationis* (Fig. 369, *ss*), the whole constituting the *plumule*. The downward prolongation of the stem (commonly but erroneously called the *radicle*, for it is *not* a little

root) ends in a very short root, which is continuous with the stem.* Under the proper conditions of heat and moisture, the root elongates and pushes out through the micropyle of the seed-coat; at the same time, the stalks of the cotyledons elongate and thus bring the plumule outside of the seed-coat, the cotyledons alone remaining. During the first few days of its growth the young plant is nourished by the starch in the cotyledons, which in this species remain during the whole process of germination beneath the ground enclosed in the seed-coat. In the common Field Bean (*Phaseolus*) the germination is the same, excepting that the hypocotyledonary stem elongates, and brings the cotyledons which have slipped out of the seed-coat above the ground.

The seed of *Ricinus* (the Castor Oil Plant) contains a large embryo surrounded by a thin layer of endosperm (Fig. 368, *I*). In its germination the root and hypocotyledonary stem elongate, and thus bring the seed-coat with the contained cotyledons above the ground (Fig. 368, *II.*). The cotyledons remain within the seed-coat until they have absorbed all of the endosperm; when this is accomplished the empty seed-coat falls away, and the freed cotyledons expand and assume to some extent the function of ordinary foliage leaves.

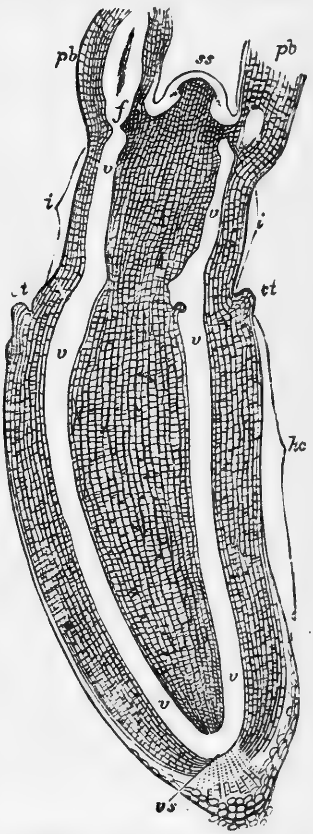


Fig. 369.—Longitudinal section of the axis of the embryo in the ripe seed of *Phaseolus multiflorus*, parallel to the cotyledons. *ss*, apex of the stem; *ws*, of the root; *ct*, swelling near insertion of cotyledons; *i*, the first internode; *pb*, the petioles of the first foliage leaves; *v*, *v*, *f*, procambium of the fibro-vascular bundles; *hc*, hypocotyledonary portion of the stem (the brace is too long in the figure). × 30.—After Sachs.

The venation of the leaves of Dicotyledons is easily studied by macerating them so as to remove the parenchyma (mesophyll), leaving only the fibro-vascular bundles. While there is as a rule a general likeness between them, there is yet an almost infinite diversity in the

* In some old books, and even a few recent ones, a structure called the collar or *collum* is spoken of. Dr. Gray very properly defines it as

details. The general disposition of the smaller veins is well illustrated by Fig. 369*a*.*

568.—The sub-class Dicotyledones is composed of thirty-six cohorts, containing in all from 150 to 200 natural orders. For convenience, the cohorts are separated into three artificial groups—the Apetalæ, Gamopetalæ, and Choripetalæ (Polypetalæ)—an arrangement which does violence to nature, separating widely many orders which are evidently closely related to each other.

I. APETALÆ. Plants whose flowers generally have but a single floral envelope (calyx), this even, in some cases, wanting.

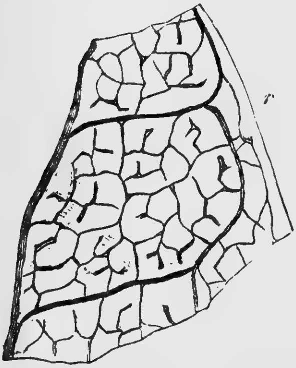


Fig. 369*a*.—Fragment of a leaf of a Dicotyledon (*Psoralea bituminosa*), showing reticulated venation. *r*, margin of leaf. × 40.—After De Bary.

569. Cohort 1.—Santalales. Herbs, shrubs, or trees, mostly parasitic, with inferior ovary, generally naked ovules—*i.e.*, no integuments—and seeds usually containing endosperm.

Order Balanophoreæ. — Fleshy leafless parasites, mostly of the tropics. One species, *Cynomorium coccineum*, of the Mediterranean region, is sometimes eaten.

Order Santalaceæ.—Leafy herbs, shrubs, or trees, mostly parasitic, numbering about 200 species, which are distributed in temperate and tropical regions.

Comandra umbellata, a perennial herb, is our most common representative of the order.

Santalum album, the Sandalwood Tree of South Asia, attains a height of seven to eight metres (25 feet). Its dark red wood is used in cabinet-making, and for burning incense in Buddhist temples. Other species from the Pacific islands also furnish sandalwood.

The Quandang Nut of Australia is the edible fruit of a small tree, *Fusanus acuminatus.*

"the name of an imaginary something intermediate between primary stem and root."

* The student who wishes to study this subject fully should consult the papers of Dr. Ettingshausen, published in *Denkschriften* and *Sitzungsberichte Wien. Kais. Akad. Wissen.* They are excellently illustrated with many "nature printed" plates.

Order Loranthaceæ. The Mistletoe Family. Evergreen shrubs, parasitic upon other Dicotyledons. About 450 species are known; these are mostly tropical.

Viscum album, the Mistletoe of England, Europe, and Northern Asia, grows abundantly upon the apple and many other trees, rarely, however, upon the oak. The viscid fruits are used in making bird-lime, and its twigs and branches are much used in Christmas decorations in England. It was held sacred by the Druids, who made use of it in their religious ceremonies.

Phoradendron flavescens, the American Mistletoe of the Southern United States, is well known. On the Pacific coast, a variety of this species is common on the oaks.

Six species of *Arceuthobium*, small brown branching parasites on Conifers, are known in the United States. *A. pusillum* occurs in the Northern States.

570. Cohort II.—Quernales. Trees and shrubs, not at all parasitic, with diclinous flowers, mostly in catkins, inferior ovaries, and seeds destitute of endosperm.

Order Cupuliferæ. The Oak Family. Trees or shrubs with simple leaves; fruits (nuts), one-celled, one-seeded, one to three enclosed in an involucre. This valuable order contains about 300 species, which are distributed mainly in the Northern Hemisphere; in the Southern Hemisphere they occur in Chili, New Zealand, and the mountains of South Australia. Most of the species are astringent, which is due to the tannin they contain.

The order is of great economic importance on account of its valuable wood, which is used not only as a fuel, but still more in the manufacture of implements and utensils, and in the construction of houses, ships, etc. It is divided into two sub-orders, which are sometimes regarded as orders.

Sub-Order Coryleæ. Shrubs and small trees.

Carpinus Americana, the Blue Beech, or Hornbeam, is a small native tree with white, fine-grained, hard wood. As the European *C. betulus* is used in turnery, doubtless our species might be also.

Corylus Avellana, the Filbert, is a shrub growing wild in Europe and Western and Northern Asia, and now cultivated in Europe and the United States. It is grown principally for its edible nuts, although the straight rod-like branches are largely used in making hoops, crates for merchandise, etc. White Filberts, Red Filberts, Cob-nuts, and Barcelona-nuts are some of the cultivated varieties. *C. Americana*, the common wild Hazel-nut of the Eastern United States, is much like the preceding, but smaller in size of shrub and nuts. Its nuts are gathered and eaten, and are occasionally found in the markets.

Ostrya Virginica, the Ironwood of the Eastern United States, is a small tree having a hard, fine-grained wood, which is valuable for fuel.

Although capable of many uses in the arts, it has been, to a great extent, neglected. The trunks of the young trees are much used for levers in saw-mills and log-yards, hence one of its popular names, Lever-wood.

Sub-Order Quercineæ. Mostly large trees.

Castanea vesca, the so-called Spanish Chestnut, is a native of Asia

FIGS. 370-74.—ILLUSTRATIONS OF QUERCUS ROBUR.

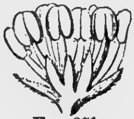


FIG. 371.

FIG. 372.

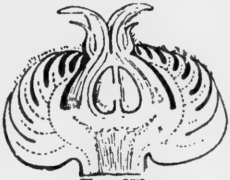


FIG. 373.

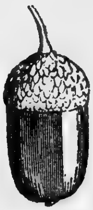


FIG. 370.

FIG. 374.

Fig 370.—Male and female branches, with a ripe fruit at the side.
Fig. 371.—Male flower. Magnified.
Fig. 372.—Female flower. Magnified.
Fig. 373.—Female flower, in vertical section. Magnified.
Fig. 374.—Vertical section of fruit.

Minor and the region eastward to the Himalayas. It is found in Central and Southeastern Europe, but it was probably introduced from the East 2000 or more years ago. It furnishes a valuable coarse-grained timber, and its fruits are the "Spanish Chestnuts" of the markets.

Several varieties occur in North Africa, Japan, and North America. *C. vesca*, var. *Americana*, our native Chestnut, of the Eastern United States, is a large tree, with smaller and sweeter nuts than the Old World variety. Its wood, which is light, coarse-grained and easily worked, is highly prized for making doors, cases, certain kinds of furniture, etc.

Fagus sylvatica, the Beech of Europe and Western Asia, supplies a hard wood much used in chair-making, turnery, and in the manufacture of wooden shoes. Purple Beech, often cultivated as a curiosity. is a variety of this species.

F. ferruginea, the common Beech of the Eastern United States, is a large spreading tree ; its wood is reddish in color, and of great hardness when dry, and is used in making carpenters' tools, and for other purposes. Its nuts, known as Beech-nuts or Beech-Mast, are nutritious, and, where abundant, are used for fattening swine.

In Southern South America, New Zealand and Australia, there are six or seven evergreen species of this genus.

The genus *Quercus* includes the Oaks, in all about 250 species, which are widely distributed in the Northern Hemisphere ; none occur beyond the equator. De Candolle (*Prodromus*, Vol. XVI.) divides the genus into six sections, four of which are exclusively Southeastern-Asiatic.

SECTION I.—The Scaly-Cupped Oaks. These include the common oaks of Europe and America. They are again subdivided into two subsections—viz., the White Oaks and the Black Oaks.

(*a*) *White Oaks.*

Quercus Robur, the British Oak, of England and the Continent of Europe. It is a stately tree, supplying a most valuable timber for all kinds of constructive purposes, in naval, civil, and military engineering. It is considered to be superior to all other kinds of oak for its timber. The bark contains tannin, and is much used in tanning. (Figs. 370–4.)

Q. Lusitanica, var. *infectoria*, of the Levant, produces the Nutgalls of commerce ; these are morbid growths on the petioles or midribs of the leaves, resulting from punctures made by an Hymenopterous insect of the genus *Cynips*. Their value lies in the tannin they contain.

Q. alba, the White Oak of the Eastern United States, stands next to *Q. Robur* in the value of its timber, which is used in this country as British Oak is in Europe.

Q. virens, the Live Oak of the Southeastern United States, and extending westward to Texas, is a large tree, twelve to twenty metres (40–60 feet) high, with spreading branches, bearing small entire evergreen leaves. Its hard and heavy wood is very strong and durable, and has been much used in ship-building.

Q. chrysolepis, the Cañon Live Oak of the cañons and mountain-sides of California, resembles the preceding in many respects, being like it an evergreen, and sometimes attaining a height of from twelve to six-

teen metres or more (40–50 feet). "It furnishes the hardest oakwood of the Pacific Coast, and is used in making ox-bows, ax-handles, etc." (Vasey).

Q. Suber, the Cork Oak, is found in Southern France, Spain, Italy, Sardinia, and, to a limited extent, in Northern Africa. It is a spreading topped tree, bearing oval, dentate evergreen leaves. Certain layers of cells in its bark retain their power of growth for a long time, and give rise to a thick mass of cork. This is removed every eight or ten years by making vertical and transverse cuts in the bark, and then peeling off all but the inner bark layers. Most of the supply of cork comes from Spain and Southern France. The tree might very profitably be grown in our Southern States and in California.

Q. cerris, the Turkey Oak of Southeastern Europe, is a fine tree with deciduous, lobed leaves, and bears a considerable resemblance to our native *Q. macrocarpa*, from which it differs, however, in requiring two years to mature its fruits. Its timber is much used for ship-building and other purposes.

(*b*) *Black Oaks.*

In this are the Black Jack (*Q. nigra*), the Red Oak (*Q. rubra*), Scarlet Oak (*Q. coccinea*), Quercitron Oak, (*Q. coccinea*, var. *tinctoria*), all of the Eastern United States. The timber obtained from these is coarse-grained, and not so durable as that of the white oaks; the two last furnish a yellow dye, Quercitron, which is derived from the bark. *Q. agrifolia*, the Field Oak of California is a broad-topped evergreen species. Its wood is of but little value.

SECTION II., the Spiny-Cupped Oak, includes but a single species, found in California.

Q. densiflora, the California Tan-bark Oak. This is a beautiful tree, often thirty metres or more in height (100 feet), with curious chestnut-like fruits.

The remaining sections contain eighty to ninety species, confined entirely to India, China, Japan, and the Malay Islands. They differ in many respects from our oaks.

Order Juglandaceæ.—The Walnut Family. Trees and shrubs with pinnately compound leaves; fruit a dry drupe, containing a hard, one-seeded nut (Figs. 380–382). This family includes about thirty species, about equally divided between North America and Asia. They possess an acrid aromatic principle, which has been used in medicine.

Juglans regia, the Walnut of the Old World, is a native of Asia Minor and the country eastward, but long cultivated in all parts of Europe, and, to some extent, in this country. The light brown wood is highly prized in England for cabinet-making, the manufacture of furniture, piano-cases, gun-stocks, etc. Its thin-shelled nuts are highly esteemed, and are imported from Europe in large quantities under the name of "English Walnuts." (Figs. 375–82.)

J. nigra, the Black Walnut of the Eastern United States, is a giant

tree, often forty to fifty metres (130–160 feet) in height. Its dark brown timber is fully as valuable as the preceding, and is used for the same purposes. It is exported in considerable quantities to England. Its

FIGS. 375–82.—ILLUSTRATIONS OF JUGLANS REGIA.

FIG. 375.

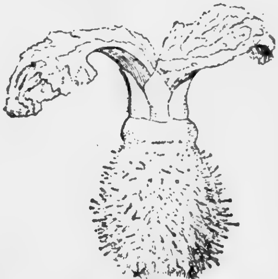


FIG. 376.

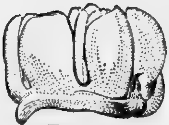


FIG. 378.

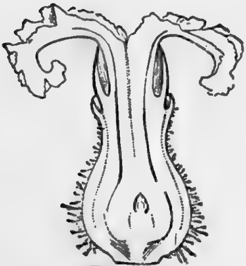


FIG. 377.

FIG. 379.

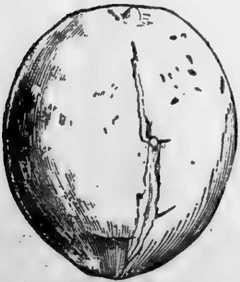


FIG. 380.

FIG. 381.

FIG. 382.

Fig. 375.—Female flower cluster. Fig. 376. Female flower. Magnified.
Fig. 377.—Female flower cut vertically. Magnified.
Fig. 378.—Male flower. Magnified. Fig. 379.—Male flower cluster.
Fig. 380.—Ripe fruit. Fig. 381.—Endocarp. Fig. 382.—Seed.

thick-shelled and stronger-tasting nuts are occasionally found in the markets.

J. cinerea, the White Walnut or Butternut, of the Eastern United States, is a smaller tree, furnishing a valuable lighter colored timber than the preceding.

Two small species occur in California, Arizona, and Texas.

Carya alba, the Shell-bark Hickory, and *C. sulcata*, both large trees, of the Eastern United States, furnish a white, tough, and hard timber, useful in the manufacture of agricultural implements, and for many other purposes where great strength is required. It is not well adapted to use in large masses, as it is liable to early destruction through decay and the ravages of wood-boring insects. The fruits, known as "Hickory-nuts," and highly prized for eating, are found in our markets, and are also exported to England.

C. olivæformis, a small tree of the Southern States, furnishes a thin-shelled edible fruit known as the "Pecan-nut."

Other species of *Carya* furnish valuable timber, and from the nuts of this and the preceding species valuable "nut-oils" used in painting are obtained.

571.—Cohort III. Asarales. Herbs, with mostly monoclinous flowers, inferior ovary, and seeds with integuments, containing minute embryo usually surrounded with endosperm.

Order Rafflesiaceæ.—Parasites upon the stems and roots of Dicotyledons. Twenty or more species are known, distributed throughout the hotter parts of the world.

Rafflesia Arnoldi, of Sumatra, is the most remarkable member of the order. It consists of a gigantic parasitic flower nearly a metre in diameter (3 ft.), with five mottled-red spreading petals. It is parasitic upon a woody climbing plant (*Cissus angustifolia*) nearly related to the Vine, and in its growth forms scarcely any stem, developing almost at once into a giant flower-bud. It was discovered in 1818 by Dr. Arnold.

Order Aristolochiaceæ.—Mostly tropical herbs, including about 200 species. Three species of *Asarum*, and three of *Aristolochia* occur in the United States.

572.—Cohort IV. Nepenthales. Climbing shrubs, with diclinous flowers, a superior three to four-celled ovary, whose many seeds contain an endosperm.

Order Nepenthaceæ.—Plants of the East Indies and Australia, of ten or twelve species, all belonging to the genus *Nepenthes*. The leaves are prolonged into a slender tendril-like organ, upon whose extremity there develops a hollow closed body, which finally becomes open by the separation of its apex in such a manner as to form a hinged lid (Fig. 383, *d*, *e*, *f*). In the cavities of these pitchers, as they

are called, a watery, slightly acid fluid is secreted ; upon their borders are secreted honey or nectar drops, which attract insects, and these falling into the fluid within are soon dissolved by it, and then absorbed by the plant for its nourishment.

Fig. 383.—Two leaves of *Nepenthes ampullaria*. *a*, short petiole ; *b*, blade or expanded part of leaf ; *c*, tendril-like prolongation of midrib ; *d*, *e*, pitcher ; *f*, its lid. In the other leaf, which is younger, the lid has not yet separated from the apex of the pitcher.—After Duchartre.

573.—Cohort V. Piperales. Mostly herbs, with spiked flowers and superior one-celled and one-seeded ovary.

Order Ceratophylleæ.—Aquatic herbs of the Northern Hemisphere.

Order Chloranthaceæ.—Shrubby plants, mostly of the tropics.

Order Piperaceæ.—The Pepper Family. Herbs, shrubs, or small trees, almost confined to the tropics ; generally with a pungent and aromatic principle. Over 1000 species are known.

We have one species of *Saururus* in the Eastern, and one of *Anemiopsis* in the Southwestern United States.

Two tropical genera, *Piper* and *Peperomia*, include nearly all the species, the first containing 620 and the second 382.

Piper nigrum is a climbing East Indian plant, with heart-shaped leaves ; it bears spikes of berries, which, when gathered green and dried, constitute the Black Pepper of commerce. The ripe berries, when dried, constitute White Pepper. Pepper is now grown in the West Indies.

P. Cubeba, whose dried unripe berries are known in pharmacy as Cubebs, is a native of the East Indies.

P. Betle, of the East Indies, is the Betel Pepper, whose bitter aromatic leaves are mixed with Areca-nut and lime to form a masticatory. (See Betel Palm, p. 466.)

From the thick rhizome of *P. methysticum* the inhabitants of many of the Pacific islands make a disgusting drink which is very intoxicating.

574.—Cohort VI. Euphorbiales. Plants with mostly diclinous flowers, with a superior two to many-celled ovary ; seeds containing endosperm.

Order Lacistemaceæ. Shrubs of tropical America.

Order Geissolcmeæ, containing a single shrub, of Southwestern Africa.

Order Penæaceæ. Evergreen shrubs of South Africa.

Order Euphorbiaceæ.—The Spurge Family. This vast group of upwards of 3000 species can not be defined by any one character. They may generally be distinguished by their three-celled ovaries and milky juice, although neither of these characters is universal throughout the order. The species range in size from small herbs to gigantic trees, and are distributed throughout all climates except beyond the Arctic Circle. They are much more abundant, however, in tropical countries than elsewhere. With few exceptions they possess an acrid principle, which is often poisonous.

Many of the species are of economic importance, a few of which only can be mentioned here.

Manihot palmata and *M. utilissima,* slender plants of tropical America, and now cultivated in many tropical countries, have thick starchy roots. The starch, separated and washed, is imported under the name of Brazilian Arrowroot. Tapioca is prepared by heating the separated and washed starch upon hot plates. Cassava is made from the crushed roots by drying the pulp without separating the starch. These three substances are highly nutritious, and are much used as food by the natives, and are, moreover, largely imported into this country. Their value is all the more remarkable from the fact that the root of the second named species above is in its raw state deadly poisonous.

Ricinus communis, the Castor Oil plant, a native of India, is now widely grown for its oily seeds, from which Castor Oil is obtained by pressure. It is extensively grown in the Mississippi Valley. In Germany it is grown for its leaves, which are fed to silkworms. It is a beautiful ornamental plant, and when grown for this purpose is called the Palma Christa.

Croton Oil from *Croton Tiglium,* and Pinhœn Oil from *Jatropha Curcas,* are drastic medicines. Gum Euphorbium, the dried milky juice

of various African and Indian species of *Euphorbia*, Cascarilla Bark and Melambo Bark from species of *Croton* in tropical America, are more or less known in pharmacy.

Hevea Guianensis and other species of the genus, natives of the northern part of South America, furnish the important substance Caoutchouc, or India Rubber. The trees are from fifteen to thirty metres in height (50 to 100 ft.), and bear trifoliate leaves resembling those of the Scarlet-runner bean in size and shape. The natives make incisions into the trees, from which the milky juice exudes, and this evaporated constitutes the crude Caoutchouc. By heating the crude product with sulphur it is hardened, and is then known as "Vulcanized rubber."

Excœcaria sebifera, the Tallow tree of China, now cultivated in the warmer parts of America, has its seeds coated with a white greasy substance, which yields a valuable tallow from which candles are made.

Aleurites Moluccana, the Candle Nut tree of India and the Pacific islands, produces a large oily fruit, which is itself burned and used as a candle, or from which a valuable oil is extracted.

The most valuable timber of the order is furnished by *Buxus sempervirens*, the Box tree of Europe and Asia. It is a small evergreen tree, with a very hard yellowish wood, invaluable in wood engraving, the manufacture of mathematical instruments, etc. Our chief supply comes from the Mediterranean ports. A dwarf variety of this species is used for bordering garden walks.

African Teak, a very heavy and hard wood from Africa, is supposed to be derived from *Oldfieldia Africana*, which has been doubtfully referred to this order.

Among the plants grown for ornament are many species of *Euphorbia*, an immense genus of 700 species, distributed very widely; in Africa they assume a Cactus-like aspect, having thick succulent stems. These and many other species are to be found in conservatories. The curious *Xylophylla*, with flat leaf-like branches, bearing flowers upon their edges, is also common.

The Sand Box tree of tropical America bears a curious many-celled fruit which when dry explodes with a loud report.

The juice of many of the species is poisonous when dropped upon the skin, or into a wound. The Manchineel tree (*Hippomane Mancinella*) of South Florida and the West Indies is extremely poisonous, but many of the stories told of it are fabulous.

Zebra Poison is the name applied to *Euphorbia arborea*; branches of it placed in water render it sufficiently poisonous to kill the animals which drink it.

575.—Cohort VII. Amentales. Woody plants, with diclinous flowers, mostly in catkins; the one or two-celled ovary superior, and the seeds with no endosperm.

Order Salicaceæ.—The Willow Family. Diœcious trees and shrubs with naked flowers—*i.e.*, the perianth wanting. The species, of which there are 180, are principally found in the North Temperate and Arctic Zones; beyond the tropics they are rare, and none occur in

Figs. 384-9.—Illustrations of Salix capræa.

Fig. 384.

Fig. 385.

Fig. 386.

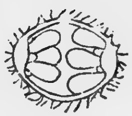


Fig. 387.

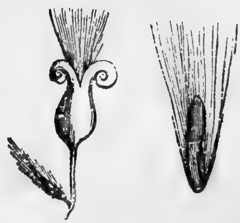


Fig. 388.

Fig. 389.

Fig. 384.—Male catkin and separate flower.
Fig. 385.—Female catkin. **Fig. 386.—Female flower. Magnified.**
Fig. 387.—Cross-section of ovary. Magnified.
Fig. 388.—Ripe fruit and seed. Magnified. Fig. 389.—Embryo. Magnified.

Australia and the South Pacific Islands. They contain a bitter astrin gent principle useful in medicine as a tebrifuge.

Two genera only are known.

Salix verminalis, S. purpurea, S. capræa, and other species of the Old World, are cultivated for basket-making.

S. Babylonica, the weeping willow of Persia, is well known under cultivation.

S. alba and other large species of Europe furnish a light firm wood, much used for many purposes.

By charring the wood a fine charcoal is obtained, much used in the manufacture of gunpowder. In the prairies of the Mississippi Valley the species last named is planted in compact rows to serve for hedges and to break the force of the violent winds.

Some of the larger of our many native species might profitably be used for their light timber, which in some cases is quite durable.

Populus Canadensis, the Cottonwood of North America, is a very large tree, whose white wood is suited to many manufacturing purposes.

The "Lombardy Poplar," a variety of *P. nigra,* and a native probably of Western and Northern Asia, and the Abele tree (*P. alba*) of Europe, are commonly grown on large grounds.

Order Casuarineæ.—Leafless trees, with pendulous Equisetum-like jointed stems. Twenty five species, mostly natives of Australia, are known. Some of them are large enough to supply a valuable timber for ship-building, and many are favorites for ornamental purposes in Australia.

Order Myricaceæ.—Monœcious or diœcious shrubs, often with a glandular waxy pubescence. The thirty to thirty-five species are widely distributed throughout the North Temperate Zone, and in tropical Asia and South Africa.

The berries of *Myrica cerifera,* the Bayberry, of the Eastern United States, and other species in Europe are covered with a wax, which is gathered and made into candles.

Order Platanaceæ.—The Plane Tree Family. A small group of five monœcious trees, with the flowers in globose catkins.

Platanus occidentalis, the Plane tree, Buttonwood, or Sycamore of the Eastern United States, is a large tree with thin white bark. Its reddish wood is valuable, and should be more used. A nearly related species occurs in California and two in Mexico. The fifth, *P. orientalis,* is the only Old World species.

Order Betulaceæ.—The Birch Family. Monœcious trees with flowers in slender catkins. The species, forty or more in number, are found throughout the North Temperate Zone, and in South America.

Betula alba, of Northern Europe, Northern Asia, and North America, is a useful species. Its wood is valuable for fuel, use in manufactures, and for making into charcoal. Its bark is made into shoes, boxes, etc.; it is used in tanning leather, and from it by distillation an oil is obtained which gives to Russia leather its peculiar scent. The people in the high north latitudes also use the cellular and starchy part of the bark for food.

The bark of *B. papyracea*, of the Eastern United States, is used by the Indians for making their "birch bark canoes."

The wood of species of *Alnus*, the Alders, is very durable when placed under the ground or water. It is also made into wooden bowls and other domestic utensils, and is in some places grown for making into charcoal.

576.—Cohort VIII. Urticales. Mostly diclinous plants, with superior one-celled ovary, and single seed mostly with an endosperm.

Order Ulmaceæ.—The Elm Family. Trees or shrubs of the North Temperate Zone, having mostly monoclinous flowers, and a watery juice. About one hundred and thirty species are known.

Ulmus campestris, the common Elm of Europe and Western Siberia, is a large tree, thirty to forty metres (100 to 130 ft.) high. Its timber is valuable for works under ground or in water, and is besides much used by wheelwrights. The tree is common in American gardens.

U. Americana, the American White Elm of the Eastern United States, and now much grown in Europe, is one of our finest looking trees, and deservedly popular as an ornament in large grounds. Its timber is valuable when used entirely under water or in the ground, or when kept continuously dry ; otherwise it decays rapidly.

U. fulva, the Slippery Elm of the Eastern United States, supplies a valuable timber, and its mucilaginous inner bark is used for medical and surgical purposes.

Celtis occidentalis, the Hackberry of the Eastern United States, is a lofty tree which furnishes a white hard timber, which is not, however, very durable.

Order Cannabineæ.—This contains the two diœcious herbs, the Hemp and the Hop.

Cannabis sativa, the Hemp, is a tall herb, two to three metres (7 to 10 ft.) in height, indigenous in the northern parts of India, but now generally cultivated in all temperate and warm regions. Under the names of *gunja*, *bhang*, *churrus*, *haschisch*, etc., the natives of India and Central Africa use the dried leaves, stems, flowers, and the resinous matter which develops on the plant. When smoked, or drank as an infusion, these are highly intoxicating. The fibre obtained from its bark is strong, and much used for cordage.

Humulus Lupulus, the Hop, a native of temperate Europe, Asia, and North America, is grown for its bitter principle, *Lupulin*, which develops in the female flower clusters, and which is much used in the manufacture of beer, ale, etc.

Order Moraceæ.—The Mulberry Family. Trees or shrubs, containing a milky juice. The order contains between 800 and 1000 species, and they are for the greater part natives of the tropics. Many

of them contain an acrid poisonous principle, while some are not only innoxious, but afford wholesome food.

Artocarpus incisa, the Bread Fruit tree, a native of the Pacific Islands, and now common in tropical countries, attains a height of from six to nine metres (20 to 30 ft.). The fleshy receptacle and agglomerated carpels form a mass as large as a man's head. This "fruit," when gathered a little before it is ripe, and baked, looks and tastes much like bread, and is largely eaten by tropical people. The Jack Fruit of India (*A. integrifolius*) is similar, but not so palatable.

Ficus Carica, the Fig, a native of Western or Southern Asia, has

FIGS. 390, 91.—ILLUSTRATIONS OF MORACEÆ.

FIG. 390.

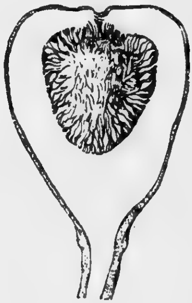


FIG. 391.

Fig. 390.—Fleshy concave receptacle of *Dorstenia*, bearing male and female flowers.
Fig. 391.—Fleshy closed receptacle of *Ficus*, cut vertically, containing male flowers above and female below.

been cultivated for ages. It is now found in all tropical and sub-tropical countries. It is grown in the Southern United States and in California. The tree attains a height of from five to six metres (16 to 20 ft.), and bears pear-shaped closed receptacles (Fig. 391), inside of which are the minute flowers. The ripened and dried receptacles constitute the Figs of commerce. Our supply comes mainly from the Mediterranean Basin.

Galactodendron utile (*Brosimum utile*), a tall tree, twenty-five metres high (80 ft.), of Venezuela, whose milky juice is used by the natives as a substitute for milk, to which it bears a close resemblance. The tree is hence called the Cow Tree.

Morus nigra, the Mulberry tree of Persia, is now cultivated in Europe and the United States for its edible fruit masses. Its leaves are used to feed to silkworms, but not to so great an extent as those of *M. alba*, the White Mulberry, which has been used from time immemorial for this purpose in China.

M. rubra, a native of the Eastern United States, bears valuable fruits.

Several of the trees of the order yield Caoutchouc. The most important of these are *Ficus elastica* of India, and *Castilloa elastica* of Mexico and the West Indies ; the first named is a common greenhouse plant.

Gum Lac is a resinous exudation collected from an Indian species of *Ficus*, whose branches have been punctured by an hemipterous insect, *Coccus lacca*.

The wood of many species is valuable.

Brosimum Guianensis, of Guiana, produces the beautifully mottled and streaked Snakewood, much prized by cabinetmakers, and for making bows.

Maclura aurantiaca, a tree eight to fifteen metres (25 to 50 ft.) high, growing in Arkansas, Texas, etc., supplies a very hard wood used by the Indians for making bows, hence one of its names, "Bow-wood." Under the name of Osage Orange, it is much used as a hedge plant. Its wood yields a coloring matter used as a dye, and from *M. tinctoria*, of the West Indies, the dye known as Fustic is obtained.

The bark of many species yields tenacious fibres ; thus from the Paper Mulberry (*Broussonetia papyrifera*), a Chinese and Japanese tree eight to fifteen metres (25 to 50 ft.) in height, the Chinese make paper, and the Pacific Islanders make cloth. One of the most remarkable is the Sack tree (*Antiaris saccidora*) of Western India ; its bark is so tenacious that after beating, it may be removed in sections, which are used for sacks for carrying rice, etc.

The Upas Tree of Java (*Antiaris toxicaria*) is poisonous, but it is by no means as virulent as it has been described. It frequently grows in volcanic valleys partially filled with carbon dioxide and other noxious gases, and to this fact is doubtless due the marvellous stories told of it. However, from its juice the natives prepare a deadly poison for their arrows.

The Banyan Tree (*Ficus Indica*) is remarkable for its numerous adventitious roots, which grow down from its horizontal branches, and thus enable it to extend its top very greatly. One on the Nerbudda, with three hundred and twenty of such supporting roots, covers an area two hundred metres (650 ft.) in diameter.

Order Urticaceæ.—The Nettle Family. Herbs, shrubs, or trees, with a limpid juice ; they occur in all climates, but mostly in the tropics. More than five hundred species are known. Many of the species possess a valuable fibrous bark. (Figs. 392–7.)

Bœhmeria nivea, the China Grass or Ramie, a perennial herbaceous plant, may fairly rival Flax in the fine and durable fibres it produces. It has been introduced into the Southern United States and California. There is still some difficulty in separating the fibres from the woody portions of the plant, and this has prevented its more extensive use.

The Stinging Nettles include ten genera, of which the most important are *Urtica*, which includes our common species, and *Laportea*, represented by our Wood Nettle; to the latter belongs the Tree Nettle, *L. gigas*, of Australia, which reaches a height of from fifteen to forty metres (50 to 130 ft.), and whose sting is so severe as to produce dangerous results.

FIGS. 392-7.—ILLUSTRATIONS OF URTICA URENS.

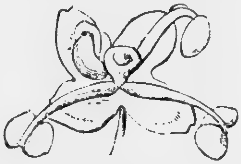


FIG. 392.

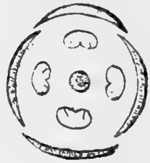


FIG. 393.

FIG. 394.

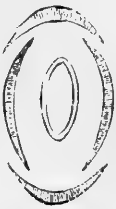


FIG. 395.

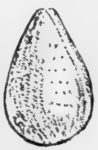


FIG. 396.

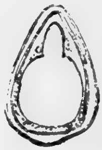


FIG. 397.

Fig 392.—Male flower. Magnified
Fig. 393.—Diagram of male flower.
Fig. 394.—Female flower. Magnified.
Fig. 395.—Diagram of female flower.
Fig 396.—Seed. Magnified.
Fig 397.—Section of seed. Magnified.

577. — Cohort IX. Daphnales. Mostly shrubs or trees, with monoclinous flowers; ovary superior, one-celled, with a single seed containing no endosperm.

Order Proteaceæ.—A family of about 1000 species, confined almost entirely to the Southern Hemisphere, and occurring in greatest abundance in Australia and South Africa. Many species, especially of the genus *Banksia*, are cultivated in conservatories. A few furnish valuable timber.

Grevillea robusta, the Silk Oak of Australia, attains a height of twenty-four to thirty metres (80 to 100 ft.), with a diameter of two metres or more, and supplies valuable timber.

Knightia excelsa is a valuable New Zealand timber tree thirty metres (100 ft.) or more in height.

Leucadendron argenteum, the Silver Tree of the Cape of Good Hope, has silvery lanceolate leaves; its wood is much used for fuel.

Protea grandiflora, the "Wagen-boom" of the same region, is used by wheelwrights in the manufacture of wagon wheels.

Order Elæagnaceæ.—A small order, of sixteen species, of trees or

shrubs, found mostly in the mountains of Southern Asia. The Oleaster (*Elæagnus hortensis*) of Southern Europe is there much planted for its odoriferous flowers; it is occasionally planted in this country.

Shepherdia Canadensis, of the Northeastern United States, and *S. argentea*, the Buffalo-Berry of the Rocky Mountains and the Great Plains, are frequently cultivated for their acid fruits, which are about as large as currants.

Order Hernandieæ, including a few tropical trees.

FIGS. 398-402.—ILLUSTRATIONS OF LAURUS NOBILIS.

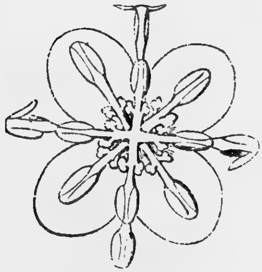


FIG. 398.

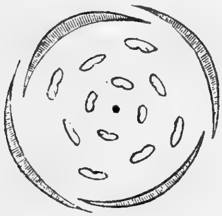


FIG. 399.

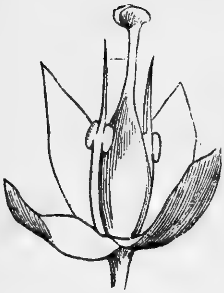


FIG. 400.

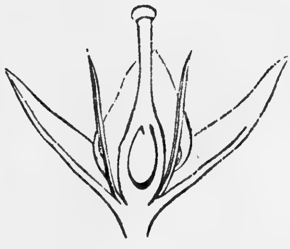


FIG. 401.

FIG. 402.

Fig. 398.—Male flower. Magnified.
Fig. 400.—Female flower. Magnified.
Fig. 402.—Diagram of female flower.
Fig. 399.—Diagram of male flower.
Fig. 401.—Section of female flower.

Order Thymelæaceæ.—Shrubby plants, mostly of the Southern Hemisphere. Of the 378 species we have in the United States but one representative, viz., the Moose-wood or "Wicopy" (*Dirca palustris*), a small shrub with exceedingly tough bark.

Daphne Mezereum, a poisonous shrub of Europe, is frequently cultivated here for its sweet-smelling flowers.

The bark of many species is used in their native countries for making

fabrics, cordage, etc. *Lagetta lintearia*, of Jamaica, is the Lace-Bark Tree, so called on account of its delicate inner bark.

578.—Cohort X. Laurales.—Herbs, shrubs, and trees, with mostly diclinous flowers; ovary superior, one-celled, the single seed sometimes with, and sometimes without endosperm.

Order Lauraceæ.—The Laurel Family. Aromatic trees and shrubs

FIGS. 403-5.—ILLUSTRATIONS OF MYRISTICA FRAGRANS.

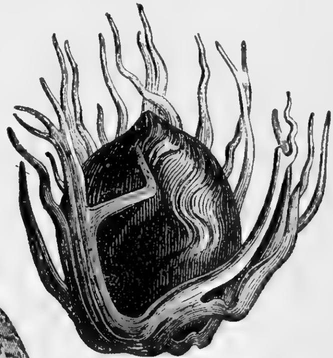


FIG. 404.

FIG. 403.

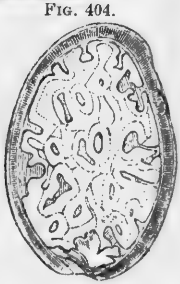


FIG. 405.

Fig. 403.—Fruit, showing seed and aril. Fig. 404.—Seed and aril.
Fig. 405.—Seed cut vertically, showing embryo below.

(rarely parasitic herbs) with free stamens, and a pendulous seed without endosperm. About 1000 species are known, occurring in the tropical and temperate climates of both hemispheres.

Laurus nobilis, the Bay or Laurel of Southern Europe, is a fine spreading-topped evergreen tree, twelve to fifteen metres (40 to 50 ft.) high. In ancient times its leaves were used to crown heroes, but now

they are made use of in flavoring custards, puddings, etc., and are put into boxes of figs to give them a factitious flavor. (Figs. 398–402.)

Umbellularia Californica (*Tetranthera Californica*), the California Laurel, resembles the preceding, and like it is evergreen. Its wood is used in cabinet-making.

Persea gratissima, a small West Indian tree, produces a delicious fruit called Avocado- or Alligator-Pear.

Among the aromatic products are Cinnamon, the bark of *Cinnamomum Zeylanicum*, a small tree of Ceylon; Cassia Bark and Cassia buds, from *C. Cassia*, of Ceylon; Camphor, a gummy matter distilled from the wood of *C. Camphora*, a tree of China and Japan; Sassafras Bark, from *Sassafras officinale*, of the Eastern United States.

The wood of the two last-named trees is valuable in cabinet-making, as is also that of the Red Bay (*Persea*) of the Southern United States.

Nectandra Rodiei, the Greenheart Tree of Guiana, is a large tree furnishing an exceedingly heavy, dark colored, and durable timber, highly valued in naval constructions.

Order Myristicaceæ.—The Nutmeg Family. Aromatic trees, with monadelphous stamens, and an erect seed containing endosperm. The seventy-five species are all tropical, and most of them occur in the Indian region. They all belong to the genus *Myristica*.

Myristica fragrans, the Nutmeg Tree of the Malay Archipelago, attains a height of six to nine metres (20 to 30 ft.); it bears a fleshy fruit of the size of a walnut and inside of this is a large seed covered with a red, branching aril (Figs. 403–4). The seed, deprived of its integuments, is the nutmeg of commerce, while the dried aril is the Mace, both well known condiments.

Some of the other species are occasionally used, but they are much less valuable.

Order Monimiaceæ.—Aromatic trees or shrubs of the tropics and south temperate zone. About 150 species are known. The Tasmanian "Sassafras Tree" (*Atherosperma moschata*), the Australian "Sassafras Tree" (*Doryphora Sassafras*), and the New Zealand "Sassafras" (*Laurelia Novæ Zelandiæ*), are large trees thirty to forty-five metres (100 to 150 ft.) high, whose timber is valuable for ship-building.

579.—Cohort XI. Chenopodiales. Monoclinous (rarely diclinous) herbs or shrubs; ovary superior, one-celled, the single seed containing endosperm.

Order Paronychieæ.—A small group of mostly herbaceous plants, the flowers generally with both sepals and petals; the latter, however, rudimentary. The order has close affinities with Caryophyllaceæ, of which it should probably be considered a sub-order.

Order Basellaceæ.—Herbaceous, often climbing plants of the tropics. One species from South America (*Boussingaultia baselloides*)

is cultivated as an ornamental climber under the name of Madeira Vine. The starchy tubers of another species, *Ullucus tuberosus*, are used in Peru as substitutes for the potato.

Order Chenopodiaceæ.—Herbs, shrubs, or rarely trees, whose flowers have an herbaceous perianth. About 500 species, distributed in all climates, are known. (Figs. 406–11.)

Beta vulgaris, the Common Beet, is a native of Southern Europe. The Sugar Beet and Mangel Wurzel are only varieties of the Common Beet; the first is extensively cultivated in France for the sugar which

FIGS. 406–10.—ILLUSTRATIONS OF BETA VULGARIS.

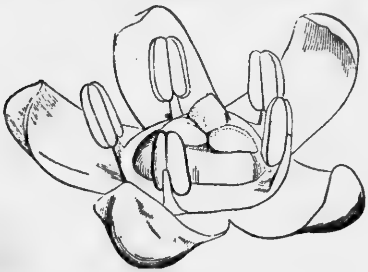


FIG. 406.

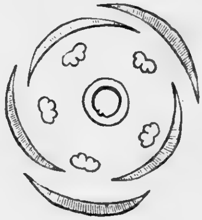


FIG. 407.

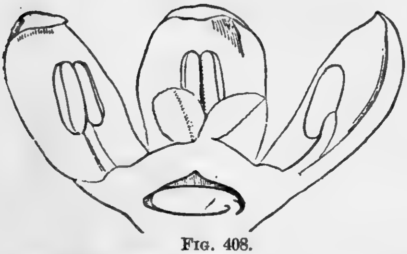


FIG. 408.

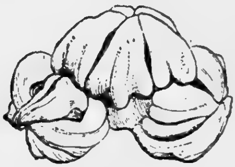


FIG. 409.

FIG. 410.

Fig. 406.—Flower. Magnified.
Fig. 408.—Section of flower. Magnified.
Fig. 410.—Seed. Magnified.
Fig. 407.—Diagram of flower.
Fig. 409.—Three fruits. Magnified.

is obtained from its sweet juice; its cultivation in this country is yet in its infancy.

Chenopodium Quinoa, a Peruvian annual, is cultivated in Western South America for its nutritious seeds, which are ground into meal, and used as an article of food.

C. ambrosioides, Wormseed, from tropical America, used somewhat in medicine, and other species of the genus, have become common weeds in fields and gardens.

Spinacia oleracea, Common Garden Spinach, is an Oriental plant much cultivated as a pot herb.

Order Amarantaceæ.—Herbs, rarely shrubs, whose flowers have a scarious perianth. The order, which contains about 500 species, is mostly tropical, a few occurring in temperate climates, but none at all in cold ones.

In India some of the species are cultivated for their starchy seeds, which are used for food.

Several species are cultivated with us for their ornamental foliage, (*Achyranthes*) or their colored inflorescence, *e.g.*, Cock's Comb (*Celosia*), Globe Amaranth (*Gomphrena*), etc.

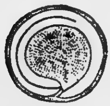


Fig. 411.—Section of seed of *Chenopodium*. Magnified.

Amarantus retroflexus and *A. albus*, are common weeds in fields; the latter, in the prairie region, grows in a globular form, and in the autumn breaks off at the root, and is blown for miles across the country. On account of this habit of growth it is called the "Tumble Weed."

Order Polygonaceæ.—The Buckwheat Family. Herbs, shrubs, or rarely trees, mostly with sheathing stipules and knotted-jointed stems; perianth often petaloid. The 600 species constituting the order are mostly natives of temperate regions.

Fagopyrum esculentum, Buckwheat, a native of Central or Northern

Figs. 412–15.—Illustrations of Fagopyrum esculentum.

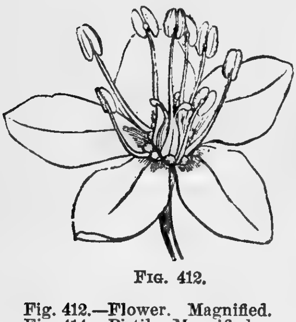


Fig. 412.

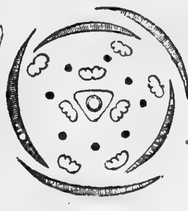


Fig. 413.

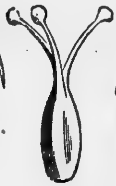


Fig. 414.

Fig. 415.

Fig. 412.—Flower. Magnified.
Fig. 414.—Pistil. Magnified.
Fig. 413.—Diagram of flower.
Fig. 415.—Fruit. Magnified.

Asia, is now extensively grown in Europe and America for its nutritious seeds, and for its honey-producing flowers. (Figs. 412–15.)

Polygonum amphibium, var. *terrestre*, a native of the United States, has been used in the Mississippi valley as a substitute for bark in the process of tanning. It contains a considerable quantity of tannin.

Rheum officinale, Oriental Rhubarb, is a native of Southeastern Asia; its roots constitute the officinal Rhubarb. Other species are often used as substitutes.

R. Rhaponticum, a native of Western Asia, is commonly grown in gardens under the name of "Pie Plant," its petioles are used for the pleasant acid they contain.

Many species are weeds of fields and gardens; such are Smartweed, and Black Bindweed (*Polygonum*, sp.), Docks and Sorrel (*Rumex*, sp.).

Order Phytolaccaceæ.—Mostly tropical herbs, sometimes shrubs or trees, usually with several free or united carpels. About eighty species are known, most of which are more or less acrid.

Phytolacca decandra, the Common Pokeweed, is our most notable representative. It is, however, a doubtful native.

Order Nyctaginaceæ.—Mostly tropical herbs, shrubs, or trees with opposite leaves and tumid joints; flowers gamophyllous. About 200 species are known. The roots of many of the species are purgative or emetic.

Abronia, of several species. *Mirabilis*, sp., the Four O'clock, or Marvel of Peru, and some others, are cultivated as ornaments.

II. GAMOPETALÆ.—Plants whose flowers generally have both sepals and petals, the latter connately united.

580.—Cohort XII. Lamiales. Plants with zygomorphic flowers, superior ovaries, indehiscent fruits, with the seeds solitary in the two to four cells.

Order Labiatæ.—The Mint Family. Aromatic herbs or shrubs, with four-angled stems and opposite leaves. The species, of which there are about 2500, are abundant in temperate and warm climates, but are rare in cool regions. We have about 200 native species in North America. (Figs. 416–18.)

Considering the size of the order, it ranks low from an economic standpoint. The aromatic herbage has led to the use of many species as domestic remedies, few of which, however, are really valuable. Nevertheless, there are many species yielding minor products which are of some value.

Hyssopus officinalis, Hyssop, a small shrub of Southern Europe, is commonly cultivated in gardens as a domestic medicine.

Hedeoma pulegioides, American Pennyroyal, is an officinal herb.

Lavandula vera, Lavender, is a shrubby plant of the South of Europe, cultivated in gardens, and used as a domestic perfume. Oil of Lavender is obtained from it by distillation.

Mentha piperita, Peppermint, introduced from Europe, yields Oil of Peppermint by distillation. It is extensively grown in Southern Michigan and New York.

Marrubium vulgare, White Horehound, of Europe, is commonly found in gardens; its dried herbage is officinal.

Rosmarinus officinalis, Rosemary, *Thymus vulgaris*, Thyme, and *Sal-*

via officinalis, Garden Sage, are small South European shrubs, now to be found in all gardens.

Catnip, Balm, Horsemint, and many others are used more or less as family medicines, for which purpose they are well suited, being harmless and feebly operative.

Several tropical species of *Salvia* are grown as ornaments, as are also *Coleus* and *Perilla*, from Southeastern Asia.

Order Verbenaceæ.—The Vervain Family. Herbs, shrubs, or trees, usually not aromatic, with mostly four-angled stems. The species number about 700, and are chiefly tropical. They generally possess a bitter and astringent principle.

With us the order is esteemed principally for its ornamental value.

FIGS. 416–18.—ILLUSTRATIONS OF LABIATÆ.

FIG. 416.

FIG. 417.

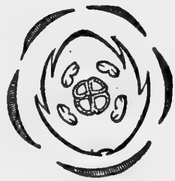


FIG. 418.

Fig. 416.—Flower of *Lamium*, side view.
Fig. 417.—Vertical section of flower. Magnified.
Fig. 418.—Diagram of flower.

Besides the several South American species of *Verbena* in common cultivation, the so-called Lemon Verbena (*Lippia citroidora*) from Chili, and the species of *Lantana* from tropical America, there are to be found in conservatories many showy species of *Clerodendron*, from Asia.

Tectona grandis, the Teak Tree of India, is a gigantic tree whose yellowish durable wood is much used in ship-building. It is said to resist the attacks of *Limnoria terebrans* when exposed in sea-water.

Vitex littoralis, of New Zealand, and other species, growing in the Indo-Australian region, are large and valuable timber trees.

Order Myoporineæ.—Mostly Australian shrubs, of no value.

581.—Cohort XIII. Personales. Plants with zygomorphic flowers, superior ovaries, and dehiscent many-seeded fruits.

Order Acanthaceæ.—The Acanthus Family. Herbs, mostly of the tropics, numbering about 1500 species. Thirty-five or forty species occur in North America, mostly, however, in the South and West. Some of the exotic species are grown in conservatories, *e.g.*, *Justicia*. *Thunbergia*, etc.

Order Pedaliaceæ.—Herbs with glandular hairs. The most important species are the Asiatic *Sesamum Indicum* and *S. orientale*, whose seeds yield an oil much used as food by the inhabitants of the tropics.

Martynia proboscidia, the Unicorn Plant of the Southwestern United States, is notable for its two-hooked fruits.

Order Bignoniaceæ.—Mostly woody plants, numbering about 500 species, and natives, for the most part, of the tropics. Many are cul-

FIGS. 419-22.—ILLUSTRATIONS OF SCROPHULARIACEÆ (*Scrophularia*, sp.).

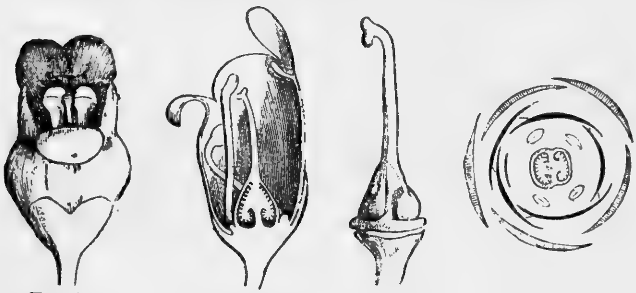


FIG. 419. FIG. 420. FIG. 421. FIG. 422.

Fig. 419.—Flower. Magnified. Fig. 420.—Section of flower.
Fig. 421.—Pistil. Magnified. Fig. 422.—Diagram of flower.

tivated for their fine flowers among these are the species of *Bignonia*; *Tecoma*, etc.

Catalpa bignonioides, the Common Catalpa of the Southern United States, is a fine tree for shade and ornament. Its wood is said to be very durable. *C. speciosa* is much hardier than the preceding.

Crescentia Cujete, the Calabash Tree of tropical America, produces a large pulpy fruit whose hard rind is used as a water-vessel.

Order Gesneraceæ.—Mostly tropical plants, represented by *Achimenes*, *Gloxinia*, *Gesnera*, etc., cultivated in conservatories.

Order Columelliaceæ.—Evergreen trees or shrubs of tropical America.

Order Lentibulariaceæ. — The Bladderwort Family. Mostly aquatic or marsh plants, of temperate and warm regions, interesting on account of the insect-catching bladders of the aquatic species. (For

the particulars as to *Pinguicula*, see Darwin's "*Insectivorous Plants*," pp. 368–394, and for *Utricularia*, pp. 395–444.)

Order Orobanchaceæ. — Leafless parasitic herbs, numbering 150 species, widely distributed. We have about a dozen native species in the United States.

Order Scrophulariaceæ.—The Figwort Family. Herbs or shrubs, rarely trees, with two-celled ovaries and central placentæ. The species, of which there are about 2000, are found in all parts of the world, extending in both hemispheres to the limits of vegetation. Many of the species contain an acrid poisonous principle. (Figs. 419–22.)

Digitalis purpurea, the Foxglove, a small plant of Europe, affords the drug Digitalis, which is officinal.

Many species are cultivated for their fine flowers ; among these are the Snapdragon (*Antirrhinum*), Monkey Flower (*Mimulus*), *Maurandia, Pentstemon, Veronica, Calceolaria*, etc., etc.

Paulownia imperialis, a small tree of Japan, is planted in the Southern States.

Verbascum Thapsus, the Common Mullein, is a weed introduced from Europe.

582.—Cohort XIV. Polemoniales. Plants with alternate leaves, regular flowers, stamens isomerous with the corolla lobes, and ovary superior.

Order Solanaceæ.—The Nightshade Family. Herbaceous or woody plants with a watery juice ; ovary two-celled, many ovuled. This large order of from 1200 to 1500 species, which are chiefly tropical, is pervaded by a more or less poisonous principle. (Figs. 423–7.)

There are, however, a few valuable food plants.

Solanum tuberosum, the Potato, is a native of America from Mexico to Chili, and a variety of it (var. *boreale*) even occurs in New Mexico. The potato was introduced into Spain in the early part of the sixteenth century, and into England by Sir Walter Raleigh in 1586, but for nearly a century from the latter date it was little used. It is now, however, grown extensively in nearly all countries. In its wild state its tubers are not more than two to three centimetres in diameter, but by culture and selection they have been increased fifteen to twenty times in bulk.

Solanum Melongena, the Egg Plant, of South America, is now grown with us for its egg-shaped edible fruits.

Lycopersicum esculentum, the Tomato, of South America, is grown in most warm and temperate countries for its wholesome fruits.

Physalis Alkekengi, the Winter Cherry or Strawberry Tomato, of the South of Europe, is grown in our gardens for its edible fruit, which is enclosed in the inflated calyx. Our native species of this genus, called commonly Ground Cherries, are valuable for food.

Capsicum annuum, of South America, and other species of the genus,

FIGS. 423-7.—ILLUSTRATIONS OF SOLANACEÆ.

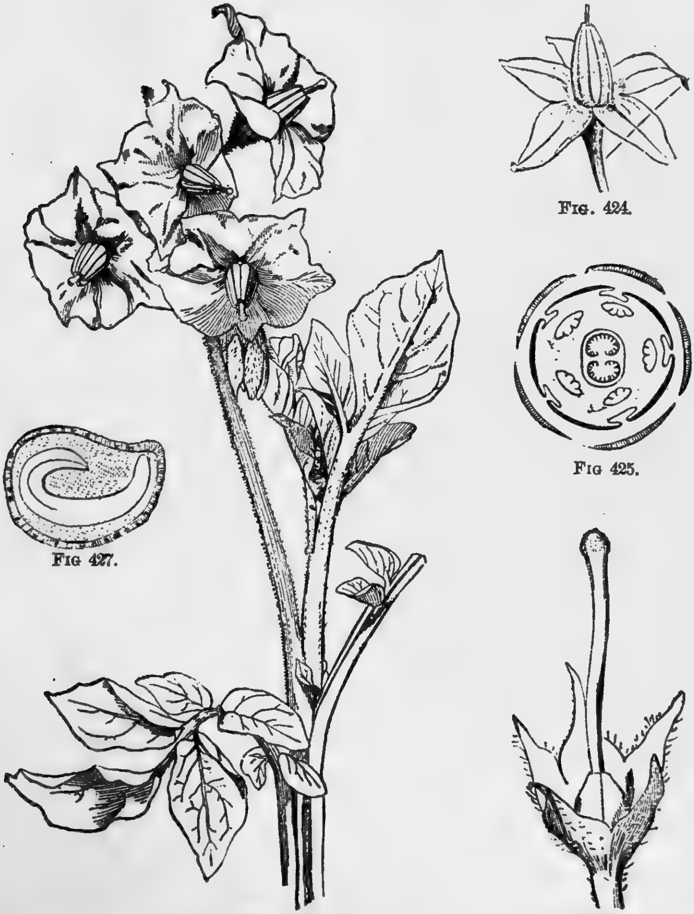


FIG. 424.

FIG 425.

FIG 427.

FIG. 423.

FIG. 426.

Fig. 423.—Flowering stem of Potato.
Fig. 424.—Flower of Bittersweet. Magnified.
Fig. 425.—Diagram of Potato flower.
Fig. 426.—Calyx and pistil of Potato. Magnified.
Fig. 427.—Section of seed of Bittersweet. Magnified.

bear exceedingly pungent pods, known as Peppers. The ground pods constitute the Cayenne Pepper of commerce.

Atropa Belladonna, the Deadly Nightshade, *Hyoscyamus niger*, Henbane, and *Datura Stramonium*, the Thorn Apple, all of the Old World, supply powerful narcotic medicines. That from the first, under the name of Belladonna, is much used by oculists to dilate the pupil of the eye.

Nicotiana Tabacum, Tobacco, a South American herb, was cultivated by the American aborigines long before the advent of Europeans. It was taken to Spain about the beginning of the sixteenth century, and to England from sixty to eighty years later. It is now extensively cultivated in many countries, especially in the United States, and is used by all the civilized nations of the globe. Two or three other species are also cultivated in different parts of the world.

Among the ornamental plants of the order are species of *Cestrum* and *Datura*, from South America and Mexico; *Lycium*, from Europe; *Petunia*, from South America, etc., etc.

The Thorn Apple mentioned above, and the Black Nightshade (*Solanum nigrum*) are common as weeds. The little black berries of the latter are made into pies and other pastry in the Mississippi Valley.

Order Convolvulaceæ.—Herbaceous climbers, rarely shrubs, often with a milky juice; ovary of 1-5 cells, each 2-, rarely 1-4, ovuled. About 800 species are known, distributed mostly in tropical and warm temperate regions. They generally possess an acrid principle.

The Common Morning-Glory (*Ipomœa purpurea*) and one or two near relatives, all from tropical America, are familiar ornamental climbers.

Ipomœa Batatas, the Sweet Potato of India, has long been cultivated in many warm and temperate climates for its nutritious roots.

The purgative drug Jalap is derived from the root of a Mexican plant *Ipomœa purga*.

Convolvulus Scammonia, of Western Asia, yields the drug Scammony, and from the wood of *C. Scoparius*, a shrubby species of the Canary Islands, Oil of Rhodium is extracted.

Cuscuta, the parasitic Dodder, includes many species.

Order Borraginaceæ.—The Borage Family. Usually hispid herbs, shrubs, or trees, with a four-parted ovary, each part one-ovuled. The 1200 species are distributed throughout the world, although they are most numerous in Southern Europe and Western and Central Asia. Many of the species possess a mucilaginous property useful in making cooling drinks, and the roots of some contain purple or brown dyes.

Anchusa tinctoria, of the South of Europe, is grown in France and Germany for its roots, which yield the red dye called Alkanet.

Among the commonly cultivated ornamental plants may be mentioned the Forget-me-not (*Myosotis palustris*) of Europe and the Heliotrope (*Heliotropium Peruvianum*) of Peru. There are several native and introduced species which are vile weeds.

Order Hydrophyllaceæ.—A small order of mostly American herbs, closely related to the preceding.

Species of *Nemophila, Phacelia, Whitlavia*, etc., are cultivated in flower gardens.

Order Polemoniaceæ.—Mostly herbs of North America and Northern Asia, numbering about 150 species.

Species of *Phlox, Gilia, Polemonium, Cobœa*, etc., are cultivated in flower gardens.

583.—Cohort XV. Gentianales. Plants with opposite leaves, regular flowers, superior ovary, and the stamens usually as many as the corolla lobes and alternate with them.

Order Gentianaceæ.—The Gentian Family. Annual or perennial herbs, with a watery juice; ovary generally one-celled, with many ovules. The species, of which there are about 500, are found mostly in temperate and cold climates. They possess a bitter principle, which has been employed in medicine. We have many very pretty wild species.

Order Loganiaceæ.—Woody plants almost entirely of the tropics, with two-celled ovaries. About 350 species are known; they contain a bitter principle which is often exceedingly poisonous.

Strychnos nux-vomica is a small tree of India, bearing an orange-like fruit containing numerous large flattish seeds (2 cm. in diameter). These seeds constitute the poisonous drug, Nux Vomica; they contain two alkaloids to which their activity is due, viz, Strychnia ($C_{21} H_{22} N_2 O_2$) and Brucia ($C_{23} H_{26} N_2 O_4 + 4 H_2 O$). The ordinary form of the first as found in the shops is a Sulphate of Strychnia.

S. toxifera, a tree of the northern parts of South America, yields from its bark and young wood the famous poison known as Curare, Urari, Ourari, Woorara, etc.

S. Tieute, a Javanese climber, furnishes the virulent Upas Tieuté or Tjettek with which the natives poison their arrows.

Order Asclepiadaceæ.—The Milkweed Family. Woody or herbaceous plants, with a milky juice; ovaries two, distinct, but with a single common stigma; pollen agglutinated into masses (pollinia). This large order of about 1300 species is chiefly tropical, being abundantly represented in America, Africa, and Asia. The milky juice contains Caoutchouc, and usually acrid and poisonous principles. But few of the species are of sufficient economic importance to demand notice. Many have a local reputation as domestic medicines. (Figs. 428–32.)

Some are favorites in the flower garden or conservatory, *e.g.*, the Wax Plant of India (*Hoya carnosa*), species of *Ceropegia, Stephanotis, Periploca*, etc. The South African Stapelias resemble *Cacti*, being fleshy and leafless

The peculiar structure of the flowers in this order has recently been shown to be for the purpose of securing the services of insects in the process of pollination.

Order Apocynaceæ.—The Dogbane Family. Woody or herbaceous plants, generally with a milky juice; ovaries two, distinct or cohering, the style always single; pollen granular. In this order of about 900 species there is very generally present a drastic purgative or poisonous principle. Most of the species are tropical, a few only extending into temperate climates.

The milky juice of several species produces Caoutchouc when evaporated, and that from a few species of *Couma, Tabernæmontana,* etc., in northern South America is used for food.

FIGS. 428–32.—ILLUSTRATIONS OF ASCLEPIAS.

FIG. 428.

FIG. 429.

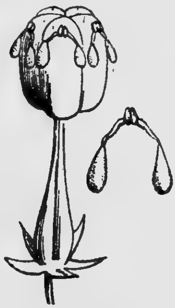


FIG. 430.

FIG. 431.

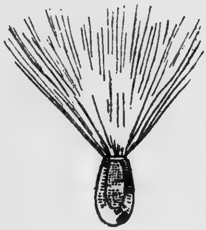


FIG. 432.

Fig. 428.—Flower, with perianth reflexed. Magnified.
Fig. 429.—Stamen, with its hood. Magnified.
Fig. 430.—Gynœcium with pollen-masses adhering to the stigma; two separated pollen-masses at the side. Magnified.
Fig. 431.—Diagram of flower.
Fig. 432.—Seed. Magnified.

Tanghinia venenifera, a tree of Madagascar, produces a fruit whose seed is the exceedingly virulent Ordeal Poison or Tanghin.

Some of the trees of the order furnish timber, which is of considerable local value.

Our native species of *Apocynum* (viz., *A. cannabinum* and *A. androsæmifolium*) possess a tough fibrous bark which was used by the Indians for making cordage, nets, etc.

Among the cultivated plants are *Nerium Oleander,* the Oleander from the Levant, an evergreen shrub or small tree with poisonous wood, bark and foliage: *Vinca,* sp. Periwinkle or, as it is erroneously called, Trailing Myrtle; *Echites, Allamanda,* etc.

Order Salvadoraceæ.—A few shrubs of the Old World tropics.

Order Oleaceæ.—The Olive Family. Woody or rarely herbaceous

plants ovaries two-celled, each cell with one to three ovules ; stamens two. The species, 280 in number, are distributed widely over temperate and tropical regions.

Olea Europæa, the Olive, probably a native of Western Asia, is now extensively cultivated in all warm temperate climates. It is a small evergreen tree, and produces a bluish oily drupe, from which by pressure Olive Oil or Sweet Oil is obtained. The wood of the Olive Tree is very hard and is used in turnery and cabinet-making.

Fraxinus excelsior, the Ash Tree of Europe and North Africa, is a large tree, yielding a white, hard, tough and elastic timber, highly prized in the manufacture of implements, in turnery, coach-making, etc. The tree is frequently planted in the United States.

F. Americana, The American White Ash of the Eastern United States, is larger than the preceding, attaining frequently a height of thirty metres (100 feet) or more. Its timber resembles that of the Ash of Europe, but is even more valuable.

F. Oregana, of Oregon and Northern California, furnishes a timber much like that of the White Ash.

F. sambucifolia, the Black Ash of the Northeastern United States, is a large tree usually found in moist situations ; the annual layers of its wood easily separate into thin strips admirably suited to make into barrel hoops, baskets, etc. Other native species also supply more or less valuable timber.

In Jamaica a species of *Linociera* produces a very hard, fragrant and excellent timber known as Jamaica Rosewood. A species of *Notelæa*, in Australia and Tasmania, yields a hard timber called Iron-wood, much used in making ship-blocks, and for other purposes where hardness is required. Several genera afford ornamental plants, *e.g.*, *Jasminum*, of many species, Jessamine ; *Syringa*, the Lilac; *Ligustrum*, the Privet; *Chionanthus*, the Fringe Tree ; *Forsythia*, etc.

584.—Cohort XVI. Ebenales.—Shrubs or trees with alternate leaves, regular flowers, and superior ovary ; ovules usually solitary in the two to many cells ; stamens generally alternate with the corolla lobes.

Order Styracaceæ.—Plants with a watery juice and monoclinous flowers. There are about 220 species in the order, found almost entirely in the tropical parts of America, Asia, and Australia.

Styrax officinale, of the Levant, yields from incisions in the bark Gum Storax, and from *S. benzoin* of the Malay Islands, Gum Benzoin is similarly obtained.

A few species afford dyes, but none are widely used.

Halesia tetraptera, the Silver-Bell or Snow-Drop Tree of the Southern United States, is a highly ornamental shrub.

Order Ebenaceæ.—The Ebony Family. Plants with a watery

juice, and mostly diclinous flowers. About 250 species are known in this order, the greater part occurring within the tropics.

Diospyros reticulata, a large tree of the island of Mauritius, produces the best of the timber known as Ebony. Ebony is also derived from *D. Ebenum* and *D. melanoxylon* of Ceylon, and *D. Ebenaster* of the Calcutta region.

D. hirsuta, of Ceylon, produces the beautiful "Calamander Wood," which is variegated with brown and yellow stripes.

D. Kaki, a Chinese and Japanese tree, bears plum-like fruits which are delicious. In our markets they are known as Chinese Dates.

D. Virginiana, the Persimmon of the Southern United States, produces fruits similar to the last, but astringent and inedible until after being frosted. Doubtless under culture this fruit might be made to equal the preceding.

Order Sapotaceæ.—Plants with a milky juice and monoclinous flowers. A tropical order of about 300 species, a few of which extend into temperate regions.

Isonandra gutta, a large tree of the Malay Islands and Borneo, is the source of the Gutta Percha of commerce. The milky juice is collected and evaporated, and then constitutes the crude Gutta Percha.

Chrysophyllum Cainito, the Star Apple, *Archas sapota*, the Sapodilla Plum, and *Archas mammosa*, the Marmalade, are West Indian trees, which bear delicious pulpy fruits.

Bassia butyracea and *B. latifolia*, both of India, and *B. Parkii*, of tropical Africa, are called Butter Trees, on account of the butter-like fatty substance obtained from their seeds by pressure.

We have eight species within the United States, found mostly along our Southern coast. Two species of *Bumelia* reach the Ohio River.

585.—Cohort XVII. Primulales.—Plants with mostly alternate leaves, regular flowers, and superior one-celled ovaries; stamens generally opposite to the corolla lobes.

Order Myrsinaceæ.—Trees or shrubs, mostly of the tropics. Three or four species barely reach the southern part of Florida.

Order Primulaceæ.—The Primrose Family. Herbs mostly with radical leaves; placenta central, free and globose; ovules many, fixed by their ventral face. Species 250, mostly of the North Temperate Zone. (Figs. 433–5.)

The order is chiefly valuable for its ornamental plants.

Primula vulgaris, the Primrose, and *P. veris*, the Cowslip, are common English plants, often referred to in poetry.

P. Sinensis, the Chinese Primrose, and *P. Auricula*, the Auricula from Southern Europe, are common in gardens and green-houses.

Cyclamen, *Dodecatheon*, and *Lysimachia* contain fine ornamental species.

Anagallis arvensis is a little weed from Europe.

Order Plantaginaceæ.—The Plantain Family. Herbs, mostly with radical leaves ; placenta central, not free ; ovules usually many, fixed by their ventral face. This anomalous order appears to be more at home in this Cohort than anywhere else. It disagrees with the characters given for the Cohort in its ovary being for the most part two-celled.

FIGS. 433–5.—ILLUSTRATIONS OF ANAGALLIS ARVENSIS.

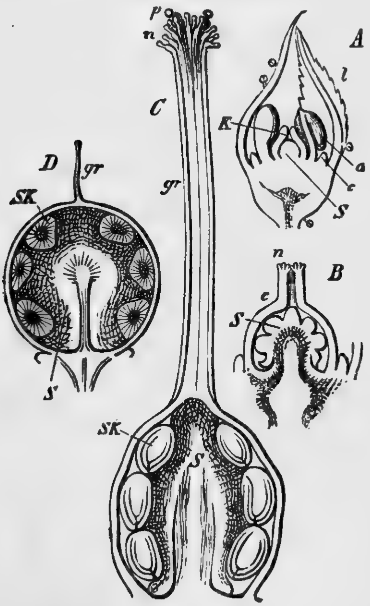


FIG. 433.

FIG. 434.

FIG. 435.

Fig. 433.—Section of young flower-bud. *l*, calyx ; *c*, corolla ; *a*, stamens ; *K*, pistil ; *S*, placenta. *B*, gynœcium further advanced. *C*, gynœcium ready for fertilization. *D*, young fruit. (After Sachs.)
Fig. 434.—Ripe fruit. Magnified.
Fig. 435.—Dehiscent fruit. Magnified. *g*, seeds.

Otherwise its agreement is so marked as to allow us to regard it as a group of degraded Primulales. The species number about fifty, and are found in all temperate regions.

Plantago major, the common Plantain, is found everywhere in dooryards.

Order Plumbaginaceæ.—Herbs or barely woody plants, with leaves radical or cauline ; ovary one-celled, one-ovuled. About 200 species are known, distributed throughout temperate climates.

Armeria vulgaris, Thrift, of Europe, is cultivated in flower-gardens.

Plumbago; several South African and East Indian species, are to be met with in conservatories.

586.—Cohort XVIII. Ericales.—Plants with regular flowers, and superior two to many-celled ovaries; stamens as many or twice as many as the corolla lobes, hypogynous or epipetalous.

Order Lennoaceæ.—Californian and Mexican leafless root-parasites.

Order Diapensiaceæ.—Low plants (six to eight species) of North America and Eastern Asia, of much botanical, but no economic interest.

Order Ericaceæ.—The Heath Family. Mostly shrubs or small trees, a few herbs, with usually alternate, simple, and entire leaves; ovary mostly five-celled, with placentæ in the axis; anthers opening by a terminal pore, rarely by a lateral slit; pollen grains compound, rarely simple.

Under these characters are included about 1700 species, which are often regarded as constituting five orders, viz., Ericineæ, Epacrideæ, Pyrolineæ, Monotropeæ, and Vaccinieæ, here to be considered as sub-orders. While, however, there are considerable differences between the plants here brought together, they are not important enough to counterbalance the many evident resemblances. The relationship subsisting between the sub-orders may be shown as follows:

VACCINIEÆ.
(Ovary inferior.)

EPACRIDEÆ ← ERICINEÆ

EPACRIDEÆ: {Stamens epipetalous or hypogynous; anthers with a slit.}

ERICINEÆ: {Gamopetalous; ovary superior; stamens hypogynous; anthers with a pore; pollen grains compound.}

PYROLINEÆ.
(Choripetalous.)

MONOTROPEÆ.
{Choripetalous; anthers with a slit; pollen grains simple.}

The Ericineæ are doubtless to be regarded as the central or main group, from which the others have diverged. In the diagram the distinguishing characters which are given for Ericineæ may be regarded as typical for the order, and under each of the other sub-orders are given the exceptional characters, or more properly, the modifications of the original ordinal characters.

Sub-Order Ericineæ.—About 1000 species of shrubs, many evergreen. Many are of great beauty, and are extensively grown as ornaments; others are good-sized trees, and furnish valuable timber. (Figs. 436–9.)

Arbutus Menziesii, the Madroña of the Pacific coast of the United States, is an evergreen tree twenty-four to thirty metres (80 to 100 ft.) in height. Its hard wood is useful in furniture-making.

Arctostaphylos pungens and *A. glauca* are large evergreen shrubs of California, which bear the name of Manzanita. The heavy, dark-colored, and fine-grained wood is used in turnery and furniture-making. The berries are eaten by grizzly bears.

A. Uva-ursi, the Bearberry of the colder portions of North America, Europe, and Asia, bears bitter and astringent leaves, which are officinal.

FIGS. 436–9.—ILLUSTRATIONS OF ERICA CINEREA.

FIG. 436.

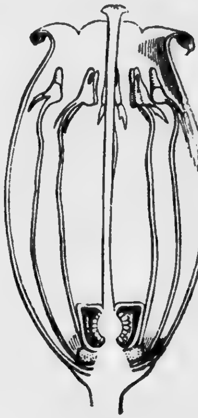


FIG. 437.

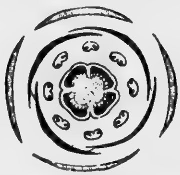


FIG. 438.

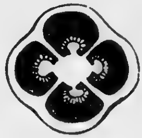


FIG. 439.

Fig. 436.—Flowering stem.
Fig. 437.—Section of flower. Magnified.
Fig. 438.—Diagram of flower.
Fig. 439.—Section of ovary. Magnified.

Calluna vulgaris, the Common Heath of Central and Northern Europe, is a low, straggling evergreen under-shrub. Its stems are made into brooms, and its flowers afford an abundance of excellent honey. It occurs in a few scattered localities in Massachusetts, Maine, Nova Scotia, and northward, but it is doubtful whether it is really indigenous to any part of the United States.

Epigæa repens, the Mayflower or Trailing Arbutus, is a low trailing plant with a woody stem, found chiefly in New England and adjacent regions. Its rose-colored fragrant flowers, which appear in early spring, are much sought for.

Erica. This large genus, including 400 or more species, is distributed in Europe, Northern Asia, and Northern and Southern Africa, reaching its maximum in the latter region. None are found in America. Many species are grown in conservatories.

Gaultheria procumbens, Wintergreen or Checkerberry, has aromatic fruit and foliage. From the latter an officinal oil is distilled.

Kalmia. A genus of beautiful plants with curious flowers; each stamen when the flower opens is bent backward, and its anther is hidden in a sac in the corolla; somewhat later the anthers escape from the sacs and the pollen is ejected. This mechanism has probably to do with the process of cross-fertilization through the agency of insects. Some of our native species are reputed to be poisonous to domestic animals, *e.g.*, *K. angustifolia,* the Sheep Laurel or Lambkill.

Rhododendron. This genus is now made to include the Azaleas as well as the true Rhododendrons. Some species become large trees (*R. arboreum* of the Himalayas), while many are highly prized as ornamental shrubs. The Great Laurel (*R. maximum*), a shrub or small tree, with large evergreen leathery leaves, grows in the Alleghany Mountains. *R. Catawbiense* and its hybrids with *R. arboreum* are extensively planted for ornaments. *R. Indica* is the Azalea of the florists; it has many varieties.

Sub-Order Epacrideæ.—About 320 species of shrubs or small trees, often with a Heath-like appearance; natives of Australia and many of the Pacific islands; only one species is found in South America. Many species are grown in conservatories, *e.g.*, *Epacris, Leucopogon, Dracophyllum,* etc.

Sub-Order Pyrolineæ.—Perennial herbs, about twenty species, all of the North Temperate Zone. They are of but little account economically or otherwise. *Chimaphila maculata,* Pipsissewa or Prince's Pine, was used by the Indians as a medicine. The dried leaves constitute the officinal drug Chimaphila.

The anomalous genus *Clethra,* including twenty-five species of shrubs and trees (American and Asiatic) is sometimes placed in this sub-order on account of its choripetalous corolla; it appears, however, to properly fall into the Ericineæ, in either the tribe Andromedeæ or Rhodoreæ.

Sub-Order Monotropeæ.—Small herbs, parasitic or saprophytic, destitute of chlorophyll; their leaves are reduced to mere bracts, and their flowers and seeds show still further degradation. Ten or twelve species are known, distributed throughout the temperate parts of the Northern Hemisphere.

Monotropa uniflora, Indian Pipe, is common throughout nearly all North America. It appears to be saprophytic.

Sarcodes sanguinea is the interesting Snow Plant, which in the Sierra Nevada Mountains of California shoots up its flesh-red stem and flowers in early spring, soon after the snow melts.

Sub-Order Vaccinieæ.—Shrubby plants, mostly of the Northern Hemisphere. Species, 320. The thick adherent calyx-tube of the flower often becomes fleshy and edible in fruit. (Figs. 440–41.)

Gaylussacia resinosa, a low shrub of the Eastern United States, produces the Black Huckleberries of the markets.

Vaccinium Pennsylvanicum, the Early Blueberry, or Blue Huckleberry, and *V. vacillans,* the Low or Late Blueberry, are common in the Northeastern United States.

V. corymbosum, the Swamp Blueberry, is also common in the Eastern United States. Besides these, other species furnish edible fruits which are sometimes found in the markets. *V. Myrtillus* occurs with us only in the Rocky and Sierra Nevada Mountains.

V. Oxycoccus, the Small Cranberry of the Northeastern United States, and the much larger *var. macrocarpon,* or Large Cranberry, which extends much further south, are valuable for their acid fruits. The variety is extensively cultivated from Massachusetts to Wisconsin.

FIGS. 440-41.—ILLUSTRATIONS OF VACCINIUM MYRTILLUS.

FIG. 440.

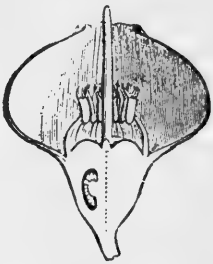


FIG. 441.

Fig. 440.—Flower. Magnified.
Fig. 441.—Section of flower. Magnified.

587.—Cohort XIX. Campanales. Plants with flowers mostly zygomorphic ; ovary inferior, two- to six-celled (rarely one-celled) ; ovules usually many in each cell.

Order Campanulaceæ.—Herbs, rarely shrubs, usually with alternate leaves and a milky juice ; ovary two- to many-celled. The 1000 species which compose this order were until recently divided between the two orders Lobeliaceæ and Campanulaceæ, which are here merged into one. The order as now constituted is represented in all regions, but most abundantly in temperate ones. All possess more or less acridity, which in some cases becomes a dangerous poison.

Lobelia inflata and *L. syphilitica* of the Eastern United States have been used in medicine ; now principally used by quacks.

L. cardinalis, the Cardinal Flower, of the Eastern United States, and several foreign species, are showy plants in the flower-garden.

Campanula medium, Canterbury Bells, and other European species, are in common cultivation.

Order Goodeniaceæ.—Mostly Australian, herbaceous plants, numbering about 200 species, of but little economic value.

Order Stylidiaceæ.—Curious herbs, about 100 in number, mostly Australian. Species of *Stylidium* are grown in conservatories.

588.—Cohort XX. Asterales. Plants with actinomorphic or zygomorphic flowers; stamens inserted on the corolla and isomerous with its lobes; ovary inferior, one-celled, one-ovuled (rarely two- to three-celled). Calyx limb often greatly reduced, forming a pappus, sometimes wanting.

Order Compositæ.—The Sunflower Family. Herbs, shrubs, or rarely trees; anthers united to each other; ovary, one-celled, containing a single erect seed destitute of endosperm. In this immense family of fully 10,000 species, distributed throughout all parts of the world, the small flowers are gathered into compact heads, which themselves often resemble single flowers. Many of the species are of great beauty, and are greatly admired as ornaments, but it is curious to observe, that despite the great size of the order, there are but few plants which are otherwise of any considerable use to man. Many are troublesome weeds.

In Bentham and Hooker's "Genera Plantarum," the 766 genera are arranged under thirteen tribes, as given below.

Tribe 1. Cichoriaceæ—Flowers all ligulate; juice milky.

Cichorium Intybus, Chicory, of Europe, is much cultivated in France and Germany. Its roots are used to adulterate coffee. *C. Endivia*, of India, is the Endive, cultivated in gardens as a salad plant.

Lactuca sativa, the Garden Lettuce, is probably a native of Asia. The dried juice of *L. virosa*, of Europe, constitutes the narcotic drug Lactucarium.

Taraxacum Dens-leonis, the Common Dandelion, is used somewhat in medicine. (Figs. 442–5.)

Tragopogon porrifolius, Salsify, of Europe, is cultivated for its edible root.

Tribe 2. Mutisiaceæ.—Flowers usually bifid, *i.e.*, two-lipped. We have but one representative, *Chaptalia tomentosa*, in Southeastern United States. They abound in tropical America.

Tribe 3. Cynaroideæ.—Flowers all tubular.

Cynara Scolymus, a native of the Mediterranean basin, is the Artichoke, grown for the thick scales of its flower heads, which are edible.

Carthamus tinctoria, a Chinese annual, is grown in gardens for its

red flowers, which are gathered and dried, constituting the dye Safflower.

Centaurea odorata and *C. moschata*, from Asia, and other European and American species, are cultivated in flower gardens.

Cnicus includes our Thistles, most of which are weeds in fields.

FIGS 442-5.—ILLUSTRATIONS OF TARAXACUM DENS-LEONIS.

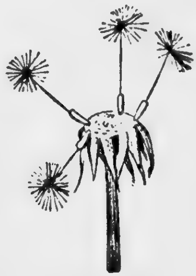


FIG. 444.

FIG. 442. FIG. 443. FIG. 445.

Fig. 442.—Head of flowers, with a bud on the right, a closed fruiting head on the left, and two leaves.

Eig. 443.—Flower. Magnified. Fig. 444.—Receptacle and fruits.

Fig. 445.—Fruit. Magnified.

C. arvensis, the so-called Canada Thistle, is in reality an Old World species. It is one of the most difficult of all our weeds to eradicate on account of its underground stems, which are tenacious of life. *C. lanceolatus*, the Common Thistle, is another introduced species.

C. pumilus, the Pasture Thistle, and *C. horridulus*, the Yellow Thistle, are indigenous.

Tribe 4. Arctotideæ.—Flowers partly tubular (forming a central disk), and partly ligulate (forming rays to the head). Natives of Africa and Australia.

Tribe 5. Calendulaceæ.—Similar to the preceding. Natives mostly of Africa and Asia.

Tribe 6. Senecionideæ.—Heads mostly with disk and ray flowers.

Arnica montana, a perennial of Europe and Siberia, from which the officinal Arnica flowers and roots are derived.

Senecio scandens, of the Cape of Good Hope, is cultivated as a house plant under the name of German Ivy.

Many other species of this genus are cultivated—*e.g.*, the so-called Cinerarias, Cacalia, Farfugium, etc. Some of the species are common weeds.

Bedfordia salicina, a native of Tasmania, attains a height of four to five metres (15 ft.). Its wood is hard, and is much prized for cabinet work on account of its beautiful grain.

Tribe 7. Anthemideæ.—Heads mostly with disk and ray flowers.

Artemisia Absinthium, the Common Wormwood of Europe, is cultivated in old gardens as a domestic remedy. In Europe an alcoholic extract called Absinthe is used as an intoxicating beverage. Some species in the Rocky Mountain region are tall shrubs, and are called Sage Brush. They furnish a valuable fuel.

Anthemis nobilis, Chamomile, and *Tanacetum vulgare*, Tansy, of Europe, are well known domestic herbs.

Chrysanthemum roseum, from Persia, *C. Indicum*, from China, and *C. coronarium*, from North Africa, are the originals of the Chrysanthemums so common in flower-gardens.

C. Leucanthemum, the Ox Eye Daisy, is a most difficult weed to eradicate.

Tribe 8. Helenioideæ.—Heads mostly with disk and ray flowers. To this belong the so-called French or African Marigolds, *Tagetes*, of several species, cultivated in flower-gardens. They are in reality natives of tropical America.

Tribe 9. Helianthoideæ.—Heads mostly with disk and ray flowers.

Dahlia variabilis and one or two other species from Mexico, are the original forms of the Dahlias of the flower-gardens.

Zinnia elegans, of Mexico, is the well-known Zinnia of the gardens.

Coreopsis, of several Arkansas and Texas species, are grown under the name of Calliopsis.

Helianthus annuus, the Common Sunflower, is a native of the Texan and Mexican regions. Aside from its ornamental use, its oily seeds are

valuable for fattening poultry, and the dried stems are good for fuel. In Russia a valuable oil is obtained from the seeds.

H. tuberosus, the so-called Jerusalem or Brazilian Artichoke, is much grown for its potato-like tubers, which are fed to cattle and swine. It is probably derived from *H. doronicoides*, of the Mississippi Valley, by long cultivation. The name "Jerusalem" Artichoke is a corruption of the Italian *Girasole—i.e.*, sunflower.

Among the weeds are the Ragweeds (*Ambrosia*), Cockleburs (*Xanthium*), Spanish Needles (*Bidens*).

Silphium laciniatum is the Compass Plant of the Mississippi Valley.

Figs. 446–50.—Illustrations of Eupatorium.

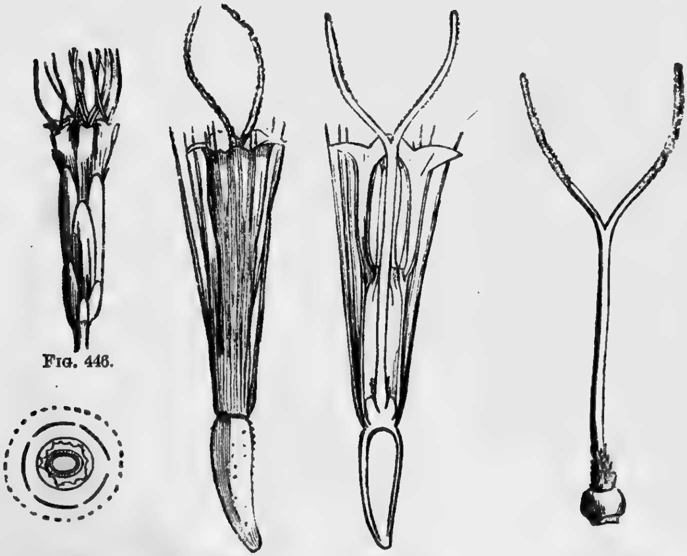


Fig. 446. Fig. 447. Fig. 448. Fig. 449. Fig. 450.

Fig. 446.—Head of flowers.
Fig. 448.—Flower. Magnified.
Fig. 450.—Pistil. Magnified.
Fig. 447.—Diagram of flower.
Fig. 449.—Section of flower. Magnified.

Its large erect pinnately lobed leaves twist upon their petioles so as to present one surface of the blade to the east and the other to the west, the two edges being upon the meridian. (Fig. 134, p. 157.)

Tribe 10. Inuloideæ.—Heads mostly with disk and ray flowers.

Helipterum Manglesii, of Australia, is one of the "Everlasting flowers," cultivated under the name of Rhodanthe, and used for winter bouquets.

Helichrysum, sp., is also cultivated for the same purpose.

Inula Helenium, Elecampane, of Europe, is cultivated in gardens for its medicinal root.

Tribe 11. Asteroideæ.—Heads mostly with disk and ray flowers.

Aside from our native species of *Aster* and *Solidago* (Golden Rods), which are ornamental, *Bellis perennis*, the English Daisy, and *Callistephus Chinensis*, the China Aster, are common in flower-gardens.

Grindelia robusta and other species are important as furnishing in the alcoholic infusion of their leaves a cure for the poisoning by Poison Ivy.

Olearia argophylla, the Musk Tree of Tasmania, attains a height of six metres (20 ft.) and a diameter of thirty cm. (1 ft.). Its wood is hard, and is used in turnery and in the manufacture of agricultural implements.

O. furfuracea and several other New Zealand species are equally valuable.

Tribe 12. Eupatoriaceæ.—Flowers all tubular. (Figs. 446–50)

Species of *Eupatorium* are used as domestic medicines. Several of the species are ornamental.

Mikania scandens, a native climber, is cultivated for ornament.

The native species of *Liatris*, Blazing Star, are also quite ornamental.

Tribe 13. Vernoniaceæ.—Flowers all tubular.

The species of *Vernonia*, known by the name of Iron-weed, are common weeds on low grounds.

Order Calyceraceæ.—A few South American herbs resembling Compositæ, but with the ovule pendulous.

Order Dipsaceæ.—Herbs, with distinct anthers and pendulous seeds, which contain endosperm. Species one hundred and twenty, mostly of the North Temperate Zone.

Dipsacus Fullonum, Fuller's Teasel, of Europe, is grown for its hard-bracted ripe heads, which are used by fullers in dressing woolen cloth.

Scabiosa contains many ornamental species.

Order Valerianaceæ.—Herbs, with distinct anthers, and three-celled, but (by absorption) one-seeded ovary ; seed without endosperm. Species about three hundred, mostly of the North Temperate Zone.

Valeriana officinalis, of Europe, has a thickish root, which, in the dried state, is the officinal Valerian.

589.—Cohort XXI. Rubiales. Plants with actinomorphic or zygomorphic flowers ; stamens inserted on the corolla and isomerous with its lobes ; ovary inferior, two- to many-celled, each cell with one to many ovules. Calyx never pappose.

Order Rubiaceæ.—Herbs, shrubs, and trees ; flowers generally reg-

ular (actinomorphic); leaves with stipules. A large order of over 4000 species, the greater part of which inhabit tropical countries. It is divided into twenty-five tribes, many of which differ so greatly from each other that they have been regarded as orders by some botanists.

The most common representatives of this order in the United States are the species of *Galium* (Bedstraw or Cleavers), *Mitchella* (Partridge Berry), and *Houstonia* (Bluets).

Cephalanthus occidentalis, the Button Bush of the Eastern United States, is a tall shrub bearing glossy green leaves and spherical heads of white, sweet-scented flowers. It deserves to be ranked among our ornamental shrubs.

Pinckneya pubens, a small tree of the Southeastern United States, is known as Georgia Bark, or Fever Tree, on account of the medicinal qualities of its bark.

Cinchona, of several species. This South American genus contains thirty or more species of trees; several of these, as *C. officinalis*, *C. calisaya*, *C. succirubra*, etc., all natives of the Andean regions of Peru, Bolivia, and New Granada, furnish the drug known as Peruvian Bark. This bark contains two important alkaloids, viz.: Cinchonia ($C_{20}H_{24}N_2O$), and Quinia ($C_{20}H_{24}N_2O_2 + 3H_2O$); the latter as a sulphate is the exceedingly valuable medicine, Quinia Sulphate, or Quinine. Cinchona trees are now cultivated in India, Java, Mauritius, and Jamaica.

FIGS. 451-5.—ILLUSTRATIONS OF COFFEA ARABICA. ALL MAGNIFIED.

FIG. 451. FIG. 452. FIG. 453. FIG. 454. FIG. 455.

Fig. 451.—Berry. Fig. 452.—Seed; ventral face.
Fig. 453.—Seed; dorsal face. Fig. 454.—Transverse section of seed.
Fig. 455.—Dorsal face of seed, cut away to show embryo.

Cephaelis Ipecacuanha, a semi-shrubby plant of Brazil, supplies from its roots the well-known emetic Ipecacuanha.

Coffea Arabica, the Coffee Tree, a native of Abyssinia, is a small-sized evergreen tree, bearing clusters of white flowers in the axils of the opposite glossy leaves. The red berries are about as large as cherries, and each contains two plano-convex seeds, the coffee seeds of commerce (Figs. 451–5). The Coffee tree was introduced into Arabia from four to five centuries ago, and into Java, by the Dutch, about two centuries ago. It has since been taken to Brazil and other parts

of South America, the West Indies, Ceylon, India, and many of the Pacific islands. Although originally from the same species, the Coffee trees now grown in different parts of the world produce seeds varying much in size, color, and quality; thus in "Mocha," from Arabia and Abyssinia, the seeds are small, of a dark yellow color, and when roasted produce an infusion of a most delicious quality; in "Java coffees" the seeds are larger, of a paler yellow color, and of scarcely inferior quality to the preceding; the coffees of Ceylon, West Indies, and Brazil (the latter particularly known as "Rio") have seeds of varying sizes, and of a bluish or greenish-gray color, and their infusions are generally inferior to those of the other varieties.

Rubia tinctoria, a perennial herb, native of the South of Europe and Western Asia, is the Madder Plant, now grown in many parts of the world for its roots, which yield the red dye known as Madder. The plant has whorled leaves and bears some resemblance to some species of *Galium.*

Among the ornamental plants of the order are many species of *Gardenia* from China and Africa, *Ixora, Portlandia, Bouvardia,* etc.

Order Caprifoliaceæ.—Mostly woody plants, with generally zygomorphic flowers and stipulate leaves. This small family of two hundred species is mostly confined to the Northern Hemisphere. A drastic and purgative principle is common in the plants of the order, but none of the species are of much importance in medicine. Many species are ornamental—*e.g.*, those of *Lonicera,* the Honeysuckles; *Symphoricarpus,* the Snowberries; *Diervilla,* the Bush-Honeysuckles, one species from Japan called Weigelia; *Viburnum,* the Snowball, etc., etc.

Sambucus, the Elder, has edible berries, which are much used for making into pies, preserves, jellies, wine, etc., in many parts of the United States.

III. CHORIPETALÆ (POLYPETALÆ of authors). Plants whose flowers generally have both calyx and corolla, the latter of separate petals.

590.—Cohort XXII. Umbellales.—Flowers usually actinomorphic; ovary inferior, one- to many-celled; ovules solitary, pendulous; seeds with endosperm.

Order Cornaceæ.—The Dogwood Family. Shrubs or trees, rarely herbs, with mostly opposite simple leaves; fruit a berry or drupe. A small order of about seventy-five species, mostly of the north temperate zone.

Several native and European species of *Cornus* are cultivated as ornamental shrubs.

Aucuba Japonica. from Japan, is a fine shrub of the flower-gardens.

The wood of *Cornus florida,* the Flowering Dogwood of the Eastern

United States, is hard and fine-grained, and is sometimes used as a substitute for Boxwood.

The wood of *Nyssa multiflora*, the Sour Gum, Tupelo, or Seppridge tree of the Eastern United States, is exceedingly difficult to split, and is much used for making hubs for wagon wheels.

Order Araliaceæ.—Shrubs or trees, rarely herbs, with mostly alternate compound leaves; fruit usually a berry or drupe. Species 340, mostly tropical.

Some of the species of *Aralia* are ornamental—*e.g.*, *A. spinosa* and *A. racemosa*, of the Eastern and Southern United States.

Hedera Helix, the English Ivy of Europe and Western Asia, is a well-known ornamental climber.

Aralia quinquefolia, Ginseng, is common in many parts of the Eastern United States. Its root is officinal.

Aralia papyrifera, a small tree of China, is the source of the Chinese Rice paper; for this purpose the pith is cut into thin sheets and then pressed flat.

FIGS. 456-60.—ILLUSTRATIONS OF FŒNICULUM VULGARE. ALL MAGNIFIED.

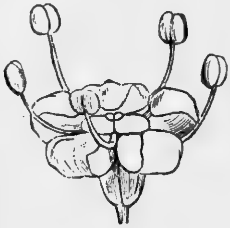


FIG. 456.

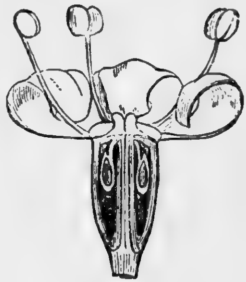


FIG. 457.

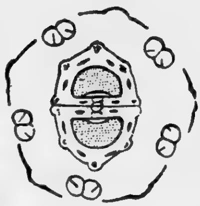


FIG. 458.

FIG. 459.

FIG. 460.

Fig. 456.—Flower. Fig. 457.—Section of flower.
Fig. 458.—Flower diagram. Fig. 459.—Ripe fruit.
Fig. 460.—Section of seed.

Order Umbelliferæ.—Herbs, rarely shrubs or trees, with alternate and usually much dissected leaves; fruit dry and indehiscent. Species 1300, found most abundantly in Northern Europe and Asia, although occurring in nearly all countries. Many contain an acrid poisonous principle, and the plants of the order may usually be regarded with suspicion. In a general way it may be said that the fruits are aromatic, and innoxious, and the green parts acrid and poisonous. (Figs. 456–60.)

The Parsnip (*Pastinaca sativa*) and the Carrot (*Daucus Carota*), both natives of Europe, are valuable and well-known food plants. In their wild state they are poisonous.

Apium graveolens, Celery, a native of Europe, is deservedly popular

as a salad. The poisonous herbage, when deprived of its green color by covering with earth, is rendered wholesome.

Among the aromatic and medicinal products may be mentioned Caraway, Coriander, Cummin, Fennel (*Fœniculum vulgare*), Dill, Aniseed, etc.

Ferula Asafœtida is a tall growing plant of Thibet and the western parts of Asia. The dried and hardened milky juice of the root is the nauseous smelling Gum Asafœtida. It is said that the Persians hold it in high esteem as a condiment. Gum Ammoniacum, Gum Galbanum, Gum Opopanax, and some other gum resins are similar strong smelling products of other plants of the same region.

Conium maculatum, Poison Hemlock, a native of Europe, but naturalized in the United States, is virulently poisonous. It is supposed to be the Hemlock used by the Greeks to poison their criminals and other offenders.

Cicuta maculata, Water Hemlock, and *Æthusa Cynapium*, Fool's Parsley, are two common poisonous plants, the first a native of the Eastern United States, the second introduced from Europe.

Monizia edulis, of the Madeiras, is a low tree, and in Australia species of *Xanthosia*, *Trachymene*, *Astrotrichia*, etc., are shrubs or small trees.

591.—Cohort XXIII. Ficoidales. Flowers usually actinomorphic; ovary mostly inferior, one- to many-celled; placentæ parietal, basilar or axile; seeds with or without endosperm.

Order Ficoideæ.—Mostly herbs, often with fleshy leaves. Species 450, mostly tropical, represented in the United States by the Carpetweed (*Mollugo verticillata*).

Mesembryanthemum crystallinum, the Ice Plant, is commonly cultivated as a curiosity.

Order Cactaceæ.—The Cactus Family. Succulent herbs, shrubs, or trees, often spiny, and generally leafless. About 1000 species are enumerated, all American (with one or two exceptions), and mostly tropical. Several of the species are common in many parts of the Old World, having long since escaped from cultivation.

Many of the species are grown in conservatories for their fine flowers, as well as on account of their curious shapes. *Cereus grandiflorus*, the Night Blooming Cereus; *Opuntia vulgaris*, the common Prickly Pear; *O. coccinellifera*, and others, are common. The last-named is fed upon by the Cochineal Insect, from which the dye Carmine is derived.

The fleshy fruits of some species are edible.

592.—Cohort XXIV. Passiflorales.—Flowers usually actinomorphic; ovary usually inferior, syncarpous, one-celled,

with parietal placentæ (sometimes three or more celled by the produced placentæ).

Order Datiscaceæ.—A curious order of four species, one of which, *Datisca glomerata*, occurs in California.

Order Begoniaceæ.—A tropical order of 350 species of herbs, mostly

Figs. 461-5.—Illustrations of Cucumis Melo.

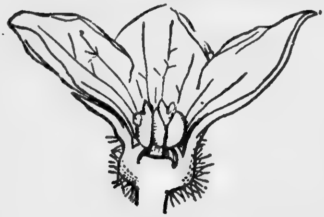


Fig. 461.

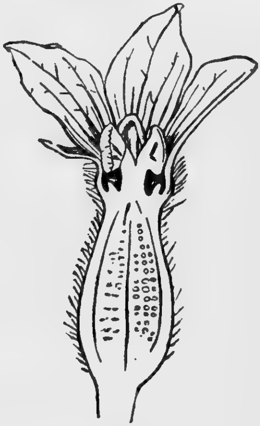


Fig. 462.

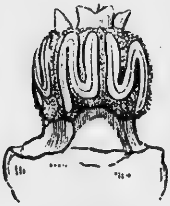


Fig. 463.

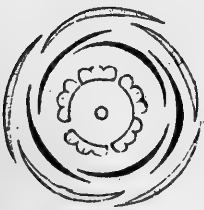


Fig. 464.

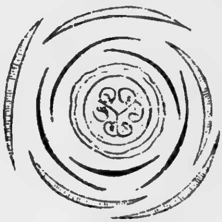


Fig. 465.

Fig. 461.—Male flower, vertical section.
Fig. 462.—Female flower, vertical section.
Fig. 464.—Diagram of male flower.
Fig. 463.—Andrœcium. Magnified.
Fig. 465.—Diagram of female flower.

American, represented in green-houses and conservatories by many species of the principal genus *Begonia*—*e.g.*, *B. Rex*, *B. Evansiana*, *B. fuchsioides*, etc.

Order Cucurbitaceæ.—The Gourd Family. Herbs or undershrubs with climbing or trailing stems and diclinous flowers; placentæ produced to the axis of the ovary and revolute. Species 470, mostly tropical. (Figs. 461–5.)

Cucurbita maxima, the large Winter Squash; *C. verrucosa*, the Crook-necked Squash; and *C. Pepo*, the Pumpkin, are well known in cultivation. Their nativity is unknown. According to Dr. Gray, the Pumpkin was "cultivated as now along with Indian Corn by the North American Indians before the coming of the whites."

Cucumis Melo, the Musk-Melon, and *C. sativus*, the Cucumber, are doubtless natives of India.

Citrullus vulgaris, the Watermelon, is a native of India.

The dried flesh and seeds of *Citrullus Colocynthis*, of the Eastern Mediterranean region, constitutes the poisonous drug Colocynth.

Lagenaria vulgaris, the common Gourd, a native of Asia and Africa, is cultivated for its fruits, which are made into bottles, drinking vessels, etc.

Luffa Ægyptica, the Towel Gourd of Egypt, is now grown in the West Indies and the Southern United States. Its fruit is somewhat larger than a Cucumber, and is very fibrous internally; its rind and seeds are removed, and the fibrous portion used as a bath sponge.

Echinocystis lobata, the Wild Cucumber or Balsam Apple of the Eastern United States, is a rapidly growing climber, valuable for arbors, screens, etc,

Order Passifloraceæ.—The Passion-Flower Family. Trees, shrubs, or herbs, mostly of the tropics. Species 250, represented in the Southern United States by four or five species of *Passiflora*, and in conservatories by magnificent climbers of the same genus from South America.

Carica papaya, the Papaw of tropical America, is a small tree, bearing large edible fruits.

Order Turneraceæ.—Tropical herbs and shrubs.

Order Loasaceæ.—Herbs of warm climates, mostly American.

Order Samydaceæ.—Trees and shrubs of the tropics.

593. Cohort XXV.—Myrtales. Flowers mostly actinomorphic; ovary usually inferior, syncarpous; placentæ in the axis (or apical, rarely basal); leaves simple, and usually entire.

Order Onagraceæ.—Herbs, shrubs, and trees, about 300 species, of temperate climates, represented in the United States by species of *Epilobium*, *Œnothera*, and other genera. In conservatories, many species of *Fuchsia* are cultivated for their beautiful flowers. They are natives of Mexico and South America.

Trapa natans, a curious aquatic plant of Central and Southern Europe, is called Water Chestnut, and its large nut-like horned fruits are nutritious. *T. bispinosa*, of Northern India, and *T. bicornis*, of China, are extensively used for food in their native countries.

Order Lythraceæ.—Herbs, shrubs, and trees, mostly of the tropics.

Species, 250, represented in the United States by a few small herbs of the genera *Lythrum, Cuphea,* etc.

Lawsonia inermis, a shrub of Western Asia, has long been in cultivation in Egypt and the adjacent countries. From its leaves the cosmetic Henna or Khenna, so much used for coloring the hair and nails, is made.

Punica granatum, the Pomegranate of India, is a bushy tree, six to nine metres high (20–30 feet), bearing deciduous leaves, and yellowish fruits about the size of an apple. The pulpy interior of the latter is prized for making cooling drinks; from it a wine is also made. Pomegranates have long been grown in the countries about the Mediterranean Sea, and are now cultivated in the warmer parts of America.

Lagerstrœmia reginæ, the Jarool or Bloodwood tree of India, is highly valued for its blood-red wood, which, being exceedingly durable in water, is much used in shipbuilding.

L. Indica, a common green-house shrub from India, is cultivated under the name of Crape Myrtle.

Sonneratia acida, an Indian tree, yields a most valuable fuel.

Physocalymma floribunda, the Tulip tree of Brazil, yields a fine wood much used for inlaying.

Order Melastomaceæ.—Trees, shrubs, and a few herbs, of the tropics. Species, 1800. We have in the United States but one genus, *Rhexia,* represented by half a dozen species. A few are cultivated in green-houses.

Order Myrtaceæ.—The Myrtle Family. Trees and shrubs (rarely herbs), with mostly opposite glandular-dotted leaves; stamens, many. A large and very difficult order of 1800 or more species, which are distributed throughout the tropics and the Southern Hemisphere.

Many of the species yield excellent fruits.

Psidium pomiferum and *P. pyriferum,* of the West Indies, and *P. Cattleyanum,* of Brazil, bear apple- or pear-shaped fruits called Guavas, highly esteemed for dessert, and for preserving. All are now extensively grown in tropical climates.

Eugenia malaccensis, the Malay Apple, and *E. Jambos,* the Rose Apple, both of the East Indies, furnish important fruits to the people of the far East.

E. pimenta, a West Indian tree, is there cultivated for its berries, which are gathered and dried before ripening, constituting the Pimento or Allspice of commerce.

E. aromatica, the Clove Tree of the Moluccas, now extensively cultivated in the East and West Indies, is prized for its spicy flower-buds, which are gathered before opening and then dried, in which state they are known as Cloves.

Bertholletia excelsa, of tropical America, is a tree thirty to forty-five metres high (100–150 feet), bearing woody-shelled fruits, ten to fifteen

cm. (4–6 inches) in diameter, inside of which are a number of rough oily seeds, the Brazil Nuts of commerce. Closely related to this is the Monkey Pot, whose woody-shelled fruit is dehiscent by a circular lid.

Many of the trees of this order furnish valuable timber.

Myrtus communis, the Myrtle Tree of Western Asia, yields a hard mottled wood much esteemed in turnery. (Fig. 466.)

Eucalyptus, sp., the Gum Trees of Australia and Tasmania. These are large stately trees, often rising to the height of fifty to one hundred metres (150–300 feet), and occasionally even exceeding this. The timber furnished by them is in some cases of great value, being tough and durable. (Figs. 467–8.)

E. globulus, the Blue Gum, is now much planted in California. Its timber is valuable, but shrinks greatly in drying. *E. marginata*, "the Jarrah or Mahogany tree of Southwestern Australia is famed for its indestructible wood, which is attacked neither by *Chelura*, *Teredo*, nor

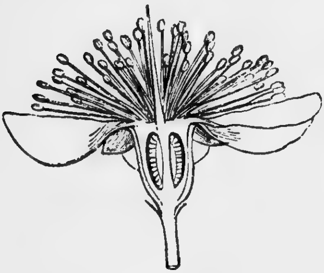


Fig. 466.

Fig. 467.

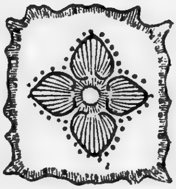


Fig. 468.

Fig. 466.—Vertical section of the flower of *Myrtus communis*. Magnified.
Fig. 467.—Vertical section of the flower bud of *Eucalyptus globulus*. Nat. size.
Fig. 468.—Transverse section of the ovary of *Eucalyptus globulus*. Magnified.

Termes, and therefore much sought for jetties and other structures exposed to sea water, also for underground work, and largely exported for railway sleepers. Vessels built of this timber have been enabled to do away with copper-plating." (*Mueller*). *E. resinifera*, the Iron Bark tree supplies a very heavy and exceedingly strong timber.

Species of *Eugenia*, *Myrtus*, etc., are grown in conservatories.

Order Combretaceæ.—Tropical trees and shrubs, about 240 species. A few species occur in South Florida.

Order Rhizophoraceæ.—Tropical trees and shrubs, about 50 species, the most important of which is the Mangrove Tree of tropical America (*Rhizophora Mangle*); it also occurs from Florida to Texas.

594. Cohort XXVI.—Rosales. Flowers mostly actinomorphic; carpels one or more, usually quite free in bud,

sometimes variously united afterwards with the calyx-tube,

Fig. 470.

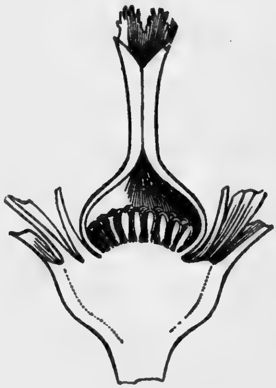


Fig. 471.

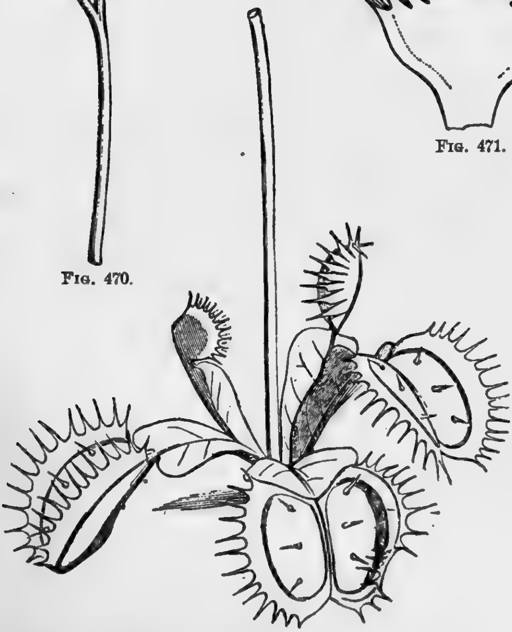


Fig. 469.

Fig. 469.—*Dionæa muscipula.* Plant with flower-stalk. Natural size.
Fig. 470—Flower-cluster. Natural size.
Fig. 471.—Pistil cut vertically. Magnified.

or enclosed in the swollen top of the peduncle; styles usually distinct.

Order Halorageæ.—Mostly aquatic herbs, about eighty species.

Order Bruniaceæ.—A few heath-like woody plants of South Africa.

Order Hamamelaceæ.—A small order of trees and shrubs, represented in the United States principally by the Witch Hazel (*Hamamelis Virginica*), and the Sweet Gum Tree (*Liquidamber Styraciflua*).

Order Droseraceæ.—The Sundew Family. Mostly bog-herbs with radical gland-bearing leaves. About 110 species are known, distributed throughout the world. This interesting little family has attracted great attention on account of the insect-catching habits of its species.

The most remarkable plant of the order is the Venus' Fly-Trap (*Dionæa muscipula*) of North Carolina. Each leaf has a rounded blade which is fringed with stiff bristles (Fig. 469), and upon the surface of each half are three sensitive hairs which, when touched, cause the tissues of the upper surface of the midrib to contract suddenly, and thus to quickly close the leaf as a book or rat-trap is closed. An insect alighting upon one of these leaves is caught by the quickly-closing sides, and is within a few days dissolved (digested) by an acidulous fluid exuded by the glands of the leaf; it is then absorbed by the leaf, and when this is accomplished the latter again opens. This plant is thus a partial saprophyte!

In the Sundews (species of *Drosera*), the leaves have stalked glands which are sensitive, and when these come in contact with an insect they cause the blade to slowly bend around it, finally enclosing it. Digestion and absorption then take place as in the previous case.

Mr. Darwin has shown that the other genera of the order are also insectivorous. (See his book, "Insectivorous Plants," London and New York, 1875, in which 367 pages are devoted to the plants of this order).

Order Crassulaceæ.—Herbs or undershrubs, usually with thick fleshy leaves. Species 400, found mostly in temperate climates. Many are in common cultivation—*e.g.*, *Bryophyllum*, the Live-leaf from tropical Africa; *Crassula*, of many species, from the Cape of Good Hope; *Cotyledon*, of many species, from Mexico and Africa; *Sedum*, Live-forever; *Sempervivum*, the Houseleek, etc.

Order Saxifragaceæ.—The Saxifrage Family. Trees, shrubs, and herbs with actinomorphic flowers, generally definite stamens, and seeds rich in endosperm. Species 540, mostly natives of temperate and cold climates.

Ribes grossularia, the Gooseberry, and *R. rubrum*, the Red Currant, both of Europe, are in common cultivation for their edible berries. The last named is also indigenous northward in this country.

Among ornamental plants are *Philadelphus*, the Mock Orange, from the Old World; *Ribes*, Flowering Currants, of the Western United States; *Deutzia*, from China and Japan; *Hydrangea*, Japanese and native; *Astilbe*, from Japan; *Saxifraga sarmentosa*, the so-called Strawberry Geranium, a fine basket plant from China.

Cephalotus follicularis, the Australian Pitcher Plant, is now regarded

as a member of this order. It is a low plant with a rosette of radical leaves, some of which resemble the covered pipes used by many Frenchmen (Fig. 472). The border of the ascidium (pitcher) in the latter is incurved and presents an obstacle to the egress of insects, which are no doubt thus captured.

Order Rosaceæ.—The Rose family. Herbs, shrubs, and trees, usually with actinomorphic flowers, generally indefinite (many) stamens, and seeds destitute of endosperm. Species, 1000, distributed throughout the world. The plants here under consideration have been arranged under several orders by some authors, on account of a part having an apparently inferior 5-celled ovary, others many superior ovaries, and still others but one superior ovary. Bentham and Hooker have arranged the seventy-one genera under ten tribes, eight of which only will be noticed here.

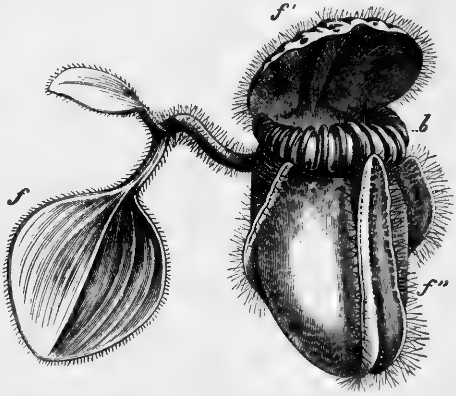


Fig. 472.—Leaves of *Cephalotus follicularis*. *f*, normal foliage leaf; *f''*, ascidium; *b*, its incurved border; *f'*. its lid. Natural size.

Tribe Pomeæ.—Shrubs and trees with simple leaves, ovaries 5 (rarely less), adnate to and frequently covered by the fleshy receptacle (and calyx ?).

Pirus Malus, the Apple, and *P. communis*, the Pear, grow wild in many parts of Europe. They have been cultivated for ages in other portions of the world. (Fig. 473.)

P. prunifolia and *P. baccata*, Siberian Crab-Apples, of the North of Asia, are in common cultivation.

P. coronaria, the American Crab-Apple, of the Eastern United States, might be made a valuable apple by cultivation.

P. Cydonia (or *Cydonia vulgaris*), the Quince, is a native of the Levant. (Figs. 474–5.)

The Hawthorns (*Cratægus*, sp.) are of some value for their fruits, and have long been favorites for hedges and ornamental purposes, Service-berries (*Amelanchier*, sp.) furnish valuable fruits, and are ornamental.

Tribe Roseæ.—Shrubs, with pinnately compound leaves; ovaries many, free, but surrounded by the fleshy receptacle (and calyx ?).

Rosa—of many species—the Roses. Not only are our native species (of which we have about a dozen) more or less cultivated for their beau-

tiful flowers, but from eighteen to twenty or more species from Europe and Asia are commonly to be found in gardens and conservatories. (Fig. 476.)

Tribe Potentilleæ.—Mostly herbs, with usually compound

FIGS. 473-5.—ILLUSTRATIONS OF TRIBE POMEÆ.

FIG. 473.

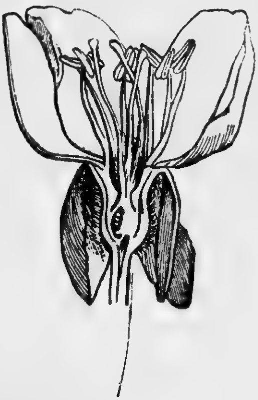


FIG. 474.

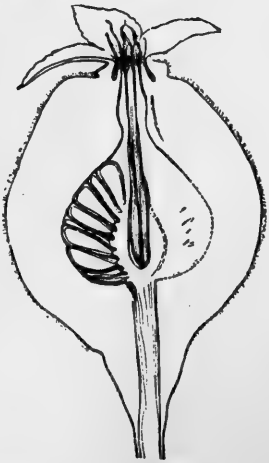


FIG. 475.

Fig. 473.—Flower cluster of *Pirus communis*.
Fig. 474.—Section of Quince flower (*Pirus Cydonia*).
Fig. 475.—Section of Quince fruit.

leaves ; carpels free, one to many, mostly on a convex fleshy receptacle ; fruits dry (achenia).

Fragaria elatior, of Europe, *F. vesca*, of Europe and Eastern United

States, and *F. Virginiana* of the Eastern United States, are the species from which the cultivated Strawberries have been derived, by high culture and crossing. (Fig. 477.)

Chamæbatia foliosa of the western slope of the Sierra Nevada Mountains in California, is a small fragrant shrub with thrice pinnate leaves, much gathered by tourists, and deserving a place in gardens.

Cercocarpus ledifolius, the Mountain Mahogany, of California, is a shrub or tree, ranging from two to fifteen metres in height (6 to 50 feet). Its heavy dark colored wood is valuable.

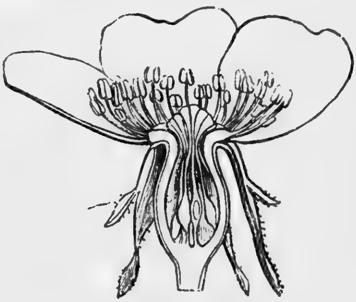


Fig. 476.—Section of the flower of *Rosa rubiginosa*. Natural size.

Tribe Rubeæ.—Mostly shrubs, differing from the preceding in having fleshy fruits (drupes).

Rubus Idæus, the Garden Raspberry, of Europe, is also cultivated to some extent in this country.

R. occidentalis, the Black Raspberry, and *R. strigosus*, the Red Raspberry, both natives of the Eastern United States, have given rise to the Common Raspberries of our gardens.

R. fruticosus, the Blackberry, of Europe, is scarcely, if at all cultivated in this country. *R. villosus*, the Wild Blackberry, of the Eastern United States, is extensively cultivated.

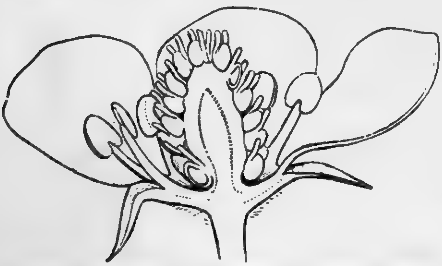


Fig. 477.—Section of the flower of *Fragaria vesca*. Magnified.

Tribe Quillajeæ.—Trees and shrubs, with mostly simple leaves, dry fruits and winged seeds. Nearly all are natives of Mexico or South America.

Quillaja saponaria, of Chili, is an evergreen tree, fifteen to eighteen metres (50 to 60 feet) high, whose bark contains Saponin ($C_{32}\ H_{54}\ O_{18}$), and is used instead of soap for washing. Under the name of Soap-bark or Quillaja-bark it is imported into this country.

Tribe Spiræeæ.—Mostly woody plants, of the Northern Hemisphere, with dry fruits. The principal genus *Spiræa*, contains many species, which, being highly ornamental, are commonly planted in flower-gardens.

Tribe Pruneæ.—Trees and shrubs, with stems yielding gum, simple, mostly serrate leaves, and solitary carpel ripening into a drupe. (Figs. 478–9.)

Prunus communis, the Almond, is a native of Western Asia, and now grown in many warm-temperate countries for its fruits. Two principal varieties are grown, viz., Sweet and Bitter; in the former the kernel is edible, whereas, in the latter, it is bitter and poisonous. An oil is expressed from both kinds.

The Peach has been until recently regarded as a distinct species (*P. Persica*), but it is now supposed to have been derived from the Almond, by long culture and selection.

P. Armeniaca, the Apricot, originally from Armenia, is now extensively grown in many countries.

P. domestica, the Plum of Europe, *P. Americana*, the Common Wild

FIG. 478.

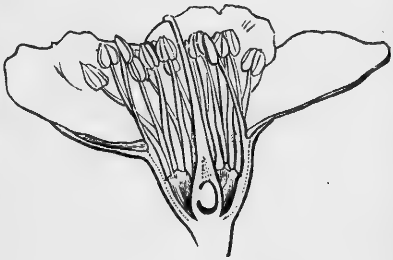


FIG. 479.

Fig. 478.—Flower cluster of *Prunus Cerasus*.
Fig. 479.—Section of flower of the Peach. Magnified.

Plum, of the Eastern United States, and *P. Chicasa*, of the Southern States, are cultivated for their excellent fruits. The second named is the original form of most of the varieties grown in the central part of the United States.

The Cherry, commonly referred to *P. Cerasus*, is probably derived from *P. avium*, the Bird Cherry, of Europe. The wood of the Bird Cherry is used in Europe for making furniture, as is also that of our Wild Black Cherry (*P. serotina*), of the Eastern United States.

Many of the foregoing have, by long and careful culture, developed double-flowered varieties, which are sometimes to be found in gardens.

Prunus nana, the Dwarf Almond, is well known in the double-flowered state.

Tribe Chrysobalaneæ.—Trees and shrubs, with simple, entire leaves. Mostly natives of tropical America, a few of tropical Asia and

Africa. Some of the latter bear edible fruits. The bark of Brazilian trees of the genera *Licania* and *Couepia* is said to contain such considerable quantities of silica, that it is burnt by the natives and used in the manufacture of pottery.

Order Leguminosæ.—The Pulse Family. Herbs, shrubs, and trees, with alternate and usually compound leaves; flowers for the most part zygomorphic; stamens usually twice as many as the petals; pistil

FIGS. 480-6.—ILLUSTRATIONS OF PAPILIONACEÆ.

(480-5, *Lathyrus odoratus.*)

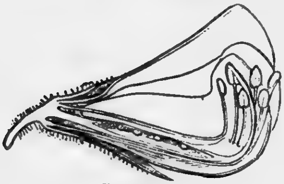


FIG. 480.

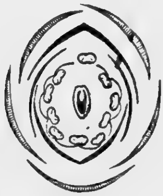


FIG. 481.

FIG. 482.

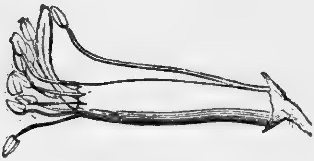


FIG. 483.

FIG. 485.

FIG. 484.

FIG. 486.

Fig. 480.—Section of flower. Magnified. Fig. 481.—Diagram of flower.
Fig. 482.—Calyx. Magnified. Fig. 483.—Stamens and pistil. Mag.
Fig. 484.—Ripe fruit. Fig. 485.—Part of fruit, with a seed.
Fig. 486.—Section of seed of *Tetragonolobus.* Magnified.

monocarpellary and free; seeds generally wanting an endosperm. A vast order of 6500 species, distributed throughout the world.

The species are usually disposed in three sub-orders, each containing many tribes.

Sub-Order I. Papilionaceæ, with zygomorphic flowers; stamens generally ten, monadelphous or diadelphous. This sub-order contains a large number of plants of great economic importance.

The *food plants* include the Pea (*Pisum sativum*), the so-called English Bean (*Vicia faba*), the Pole Bean (*Phaseolus vulgaris*), the Field Bean

(*P. nana*), the Lima Bean (*P. lunatus*), probably all from India and Western Asia.

Many more species are now cultivated in India, such as Chowlee, Black Grain, Soy, Pigeon Pea, Lentils, etc.

The Peanut (*Arachis hypogæa*), a native of South America, is now an important food plant in the West Indies and Africa. After the fertilization of the erect yellow flowers, the peduncles bend down and the young pods are thrust into the ground, where they ripen. This curious habit, which must have been at first a protective one, is perpetuated in cultivation, although the need of it apparently no longer exists.

The forage plants include the Red Clover (*Trifolium pratense*), the White Clover (*T. repens*), Lupine (*Lupinus albus*), Lucerne (*Medicago sativa*), Sanfoin (*Onobrychus sativa*), Tares or Vetches (*Vicia sativa*), all from Europe and the countries adjacent to the Mediterranean Sea. Many others are grown less extensively.

Of the timber trees, the following are the most important :

Robinia Pseud-Acacia, the Locust Tree of the Eastern United States, yields a very strong and durable timber.

Dalbergia nigra, a large tree of Brazil, produces the finest Rosewood.

D. latifolia, of India, produces the Indian Rosewood.

The valuable dye Indigo is obtained from *Indigofera tinctoria*, a native of India. The flowering plants are cut and placed in vats of water ; after remaining for a time, the water, now colored, is drawn off, and after several intervening processes, the coloring matter is allowed to settle to the bottom ; this when dried is crude indigo.

The wood of *Pterocarpus santalinus*, a tree of India, when reduced to chips, is the red dye known as Red Sandal-wood, or Saunders.

Camwood, another red dye, is obtained in a similar manner from *Baphia nitida*, a West African tree.

Some species furnish gums and balsams, which are of use in the arts.

Gum Tragacanth is derived from a low shrubby plant, *Astragalus tragacantha*, growing in Western Asia.

Gum Kino is produced by large trees of India and Africa belonging to the genus *Pterocarpus*.

Balsam of Peru and Balsam of Tolu are the products of species of *Myroxylon*, in Central and South America.

But one important medicinal product is furnished by this sub-order, viz., Liquorice, the dried roots of *Glycyrrhiza glabra*, a native herb of the South of Europe.

In India species of *Crotalaria* and *Sesbania* are extensively cultivated for their strong and durable fibre, much used for making cordage and coarse cloth.

Of the many ornamental plants, the following only can be mentioned, viz., species of *Lupinus, Cytisus, Laburnum, Petalostemon, Caragana, Robinia, Wistaria, Phaseolus, Lathyrus, Sophora*, etc., etc.

Desmodium gyrans, an East Indian plant, is remarkable for the spontaneous movements of its leaves. The leaves are compound, the terminal leaflet being large, while the lateral ones are small; under proper conditions the lateral leaflets alternately rise and fall by quick jerks, continuing this for hours without any apparent external cause.

Sub-Order II. Cæsalpinieæ, with flowers zygomorphic or actinomorphic; stamens generally ten, usually distinct.

The Tamarind is the fruit of a North African and East Indian tree of this sub-order, *Tamarindus Indica.*

Senna, a medicinal drug, is the dried foliage of African and East Indian species of *Cassia.*

Gum Copal, much used in making varnishes, is derived, at least in part, from East Africa and Madagascar trees belonging to the genera *Trachylobium* and *Hymenæa.*

Copaiva Balsam is obtained from Brazilian trees (*Copaifera*, sp.) by making deep incisions into the trunks.

The pulverized wood of *Cæsalpina echinata*, a Brazilian tree, yields the red dye Brazil-wood; that from *Hæmatoxylon Campeachianum*, a small tree of Central America, is the well-known and valuable dark-red dye Logwood.

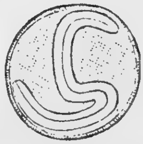


Fig. 487. — Cross-section of the seed of *Cassia tora*, showing the abundant endosperm.—Magnified.

Many timber trees are of great value—*e.g.*, the Mora Tree of Guiana (*Dimorphandra Mora*), whose heavy durable timber is in great repute in the British navy yards; the West India Locust (*Hymenæa Courbaril*), used in ship-building; the Honey Locust of the Eastern United States (*Gleditschia triacanthos*), which furnishes a valuable timber used by wheelwrights for making hubs; the Kentucky Coffee Tree of the Eastern United States (*Gymnocladus Canadensis*), whose red wood somewhat resembles Mahogany; the Judas Trees (*Cercis*, sp.), whose wood is prized in Europe for cabinet-making.

Sub-Order III. Mimoseæ.—Flowers actinomorphic, small, and generally collected into close heads or spikes; stamens distinct, two to many times the number of petals.

One of the most important of the vegetable gums—Gum Arabic or Gum Acacia—is furnished by trees of this sub-order belonging to the genus *Acacia.* The greatest supply is obtained from *A. vera* and *A. Arabica*, natives of Northern Africa, Arabia, and the East Indies.

The genus *Acacia* is abundantly represented in Australia, where many of its species, called Wattles, yield most excellent timber. That of *A. melanoxylon* "is most valuable for furniture, railway carriages, boat-building, casks, billiard-tables, piano-fortes (for sounding-boards and actions), and numerous other purposes. The fine-grained wood is cut into veneers. It takes a fine polish, and is considered equal to the best walnut." (*Mueller.*)

Lysiloma Sabicu, a large Cuban tree, yields a hard and very durable timber, highly valued for ship-building and for other purposes.

Many species of *Acacia* and *Mimosa* are in cultivation in gardens and conservatories.

Mimosa pudica, from South America, is interesting on account of its extreme sensitiveness to a touch or jar. On this account it is commonly known as the Sensitive Plant. Its leaves expand in the light and contract in darkness, and in the proper temperature close at once upon

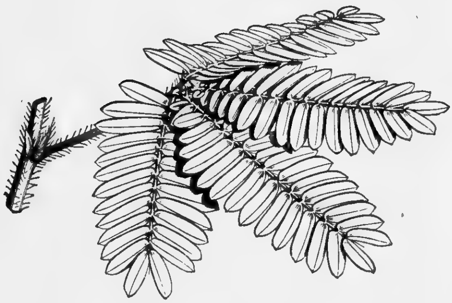


FIG. 488.

FIG. 489.

Fig. 488.—Expanded compound leaf of *Mimosa pudica*.
Fig 489.—Closed leaf of the same.

being touched or jarred, opening again, however, in a few minutes (Figs. 488–9).

Order Connaraceæ.—Trees and shrubs of the tropics, one of which, *Connarus Lambertii* of Guiana, furnishes the beautiful Zebra-wood.

595.—Cohort XXVII. Sapindales. Shrubs and trees, with usually compound leaves. Flowers often zygomorphic and diclinous; ovary superior; seeds usually without endosperm.

Order Moringeæ.—Contains three Old World trees, of doubtful affinity.

Order Coriarieæ.—Shrubs of one genus and three to five species, found in the Mediterranean region, the Himalayas, Japan, New Zealand, and South America. Their affinities are very obscure.

Order Anacardiaceæ.—The Cashew Family. Trees and shrubs, with gummy or milky-resinous juice, often poisonous; fruit usually a drupe. Species about 450, chiefly found in the tropics. The common

representatives of this order in this country are species of *Rhus*, of which *R. typhina* and *R. glabra*, Sumach, are highly ornamental, as well as useful, their young shoots and leaves containing much tannin and being much used in tanning.

Rhus Toxicodendron, the Poison Ivy, and *R. venenata*, the Poison Sumach, both of the Eastern United States, and *R. diversiloba*, the "Poison Oak" of California, are very poisonous, causing in many persons a severe cutaneous eruption.

Mangifera Indica, of India, but now grown in most warm climates, produces the excellent fruit known as the Mango.

The Cashew Nut is the product of a large West Indian tree, *Anacardium occidentale*, and the Pistachia Nut of a tree of Western Asia, *Pistacia vera*.

Mastic, a resinous material used in fine varnishes, is obtained by making incisions into the stem of *Pistacia Lentiscus*, a small tree of the Mediterranean region. Japan Lacquer, so much used by the Japanese in the manufacture of many wares, is obtained in a similar way, from *Rhus vernicifera*, and probably other species. Japanese Wax is derived from the waxy-coated seeds of *R. succedaneum*, a tree of China and Japan.

Schinus molle, a Peruvian shrub, is much grown for ornament in the gardens of California and Italy.

Order Sabiaceæ.—Trees and shrubs, mostly of the tropics.

Order Sapindaceæ.—Trees and shrubs (rarely herbs), mostly with compound or lobed leaves. Species from 600 to 700, widely distributed. This order includes five well-marked sub-orders, as follows:

Sub-Order I. Staphyleæ, with actinomorphic flowers, and seeds with endosperm. Represented in the Eastern United States by the native ornamental shrub, the Bladder Nut (*Staphylea trifolia*).

Sub-Order II. Melianthеæ, with zygomorphic flowers, and seeds with endosperm. Old World trees and shrubs.

Sub-Order III. Dodonæeæ, with actinomorphic flowers, and seeds without endosperm; leaves alternate.

Ptæroxylon utile, the Sneezewood Tree of the Cape of Good Hope, furnishes a hard and durable timber, as also a New Zealand tree, *Alectryon excelsum*.

Sub-Order IV. Acerineæ, with actinomorphic flowers, and seeds without endosperm; leaves opposite. (Figs. 490–2.)

The genus *Acer*, the Maples, contains nearly all the species.

A. campestre, the Common Maple of Europe, *A. Pseudo Platanus*, the Sycamore Maple of Europe and Western Asia, and *A. platanoides*, the Norway Maple of Europe, are valuable timber trees, occasionally planted here as ornaments.

A. saccharinum, the Sugar Maple, *A. rubrum*, the Red Maple, and

A. dasycarpum, the Silver Maple, all of the Eastern United States, furnish timber much used in the manufacture of furniture.

From the sweet sap of the first much sugar is made in the Northern United States. Its wood also is harder, and is known as Hard Maple, to distinguish it from Soft Maple, derived from the other species.

A. macrophyllum, the Large Leaved Maple, and *A. circinatum*, the

FIGS. 490-2.—ILLUSTRATIONS OF ACER PSEUDO-PLATANUS.

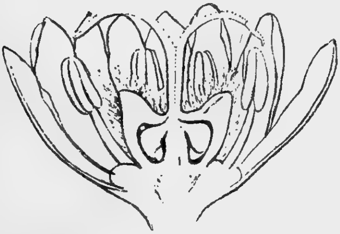


FIG. 490.

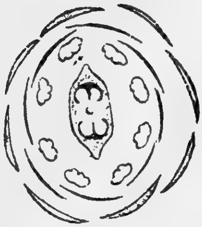


FIG. 491.

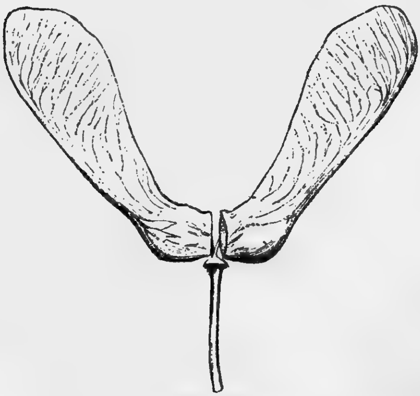


FIG. 492.

Fig. 490.—Section of flower. Magnified. Fig. 491.—Flower diagram. Fig. 492.—Ripe fruit.

Vine Maple, both of California and Oregon, yield a hard and close-grained timber.

Negundo aceroides, the Box Elder of the Eastern United States, is a fine ornamental tree. *N. Californicum*, of the Pacific Coast, is much like the preceding.

Sub-Order V. Sapindeæ.—Flowers actinomorphic or zygomorphic; seeds without endosperm; leaves mostly alternate. (Fig. 493.)

Æsculus glabra, the Ohio Buckeye, and several other species, are native ornamental trees of the sub-order.

Æ. Hippocastanum, the Horse-Chestnut of the Old World, is commonly planted.

Kœlreuteria paniculata, a Chinese tree, and *Cardiospermum Halicacabum*, the Balloon Vine of the Southern United States, are cultivated as ornaments.

Nephelium Litchi, a small Chinese tree, produces the pulpy edible fruits imported under the name of Litchi. *N. Longan* produces the similar fruit called Longan.

Melicocca bijuga, a tree of Guiana, yields a hard and heavy timber, and from *Cupania pendula*, of Australia, is obtained Tulip Wood, which, in some respects, resembles Mahogany.

The stem of the climbing plant, *Paullinia curassavica*, of Venezuela, is made into the walking-sticks called "Supple Jacks."

Fig. 493.—Diagram of the flower of *Æsculus*; the normal circle of stamens shaded black; of the interposed ones but two are fully developed, shaded lighter, the abortive ones represented by dots.—After Sachs.

596. — Cohort XXVIII. Celastrales. Flowers actinomorphic and monoclinous; ovary superior entire; seeds usually with endosperm.

Order Ampelideæ. — Mostly climbing shrubs, with nodose stems, bearing petioled alternate leaves; tendrils and flower clusters opposite to the leaves. About 250 species are known; they abound in the tropics and are much rarer in temperate climates.

Vitis is the principal genus; it contains all the true Vines (grape producing), and many others whose fruits are inedible. (Figs. 494–501.)

Vitis vinifera, the Vine of the Old World, has been under cultivation from time immemorial. It is indigenous to Southern Asia, from whence it has been carried to nearly all parts of the world. Its varieties are almost innumerable. From those grown in Southern Europe wines and raisins are made, the latter being merely the sun-dried grapes.

In the United States the Old World Vine is grown in the Southern and Pacific Coast States, and in the latter region fine raisins are made. In other portions of this country only the native species are grown, viz.:

V. Labrusca, the Northern Fox Grape; from this have originated most of the common varieties, as Catawba, Concord, Isabella, etc.

V. æstivalis, the Summer Grape, from which we have obtained the Virginia Seedling, Herbemont, etc.

V. riparia, the River-bank Grape, which has produced the Taylor Bullit, Delaware, and Clinton.

V. vulpina, the Southern Fox Grape, which has given rise to the Scuppernong and other varieties.*

From these American grapes excellent wines are now made; but no raisins have yet been made from them.

The Virginia Creeper, *Ampelopsis quinquefolia* (or *Vitis quinquefolia*),

FIGS. 494-501.—ILLUSTRATIONS OF VITIS VINIFERA.

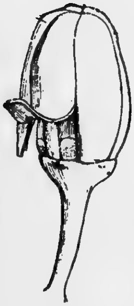


FIG. 494.

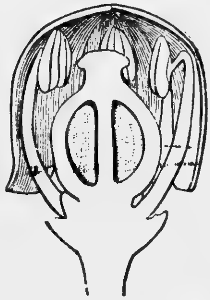


FIG. 495.

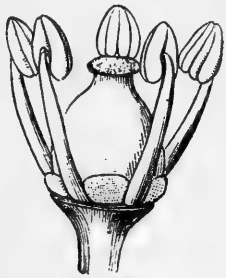


FIG. 496.

FIG. 497.

FIG. 498.

FIG. 499.

FIG. 500.

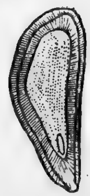


FIG. 501.

Fig. 494.—Flower bud. Magnified.
Fig. 495.—Section of flower-bud. Magnified.
Fig. 496.—Flower without corolla. Magnified.
Fig. 497.—Flower diagram. Fig. 498.—Fruit.
Fig. 499.—Seed. Magnified. Fig. 500.—Cross-section of seed. Magnified.
Fig. 501.—Vertical section of seed. Magnified.

is one of our finest native ornamental climbers.

Javan and Sumatran species of *Vitis,* formerly referred to *Cissus*, are common in conservatories.

Order Rhamnaceæ.—Trees and shrubs, often spinescent, bearing simple, usually alternate leaves; flowers with valvate calyx lobes. Species 430. Inhabitants for the most part of warm and temperate regions. Many possess a purgative principle.

* This distribution of the cultivated varieties is that made by Dr George Engelman. *American Naturalist*, 1872, p. 539.

The fruits of some species of *Rhamnus* yield yellow or green dyes, which are of considerable importance.

The wood of *R. frangula*, of Europe, is used for making the best charcoal for the finest gunpowder.

Species of *Zizyphus* in Africa and India produce edible fruits, one of which is the Jujube.

Rhamnus catharticus, the Buckthorn of Europe, is planted in this country for hedges.

Order Stackhousieæ.—Small herbs, mostly confined to Australia.

Order Celastraceæ.—Small trees and shrubs, often climbing, bearing simple, usually alternate leaves; flowers with imbricate calyx lobes. Species about 400, natives of temperate and tropical regions.

Celastrus scandens, the Climbing Bittersweet of the Eastern United States, is ornamental, and is planted in this country and Europe.

Euonymus atropurpureus, the Waahoo, or Burning Bush of the Eastern United States, is also found in gardens.

The wood of *E. Europæus* of Europe is compact and capable of being split into very fine pieces, and is used by watch-makers under the name of Dogwood. It is also used for skewers, shoe-pegs, etc.

From the leaves of *Catha edulis*, an East African shrub, a decoction is made which produces an agreeable excitement. The leaves themselves are sometimes chewed.

597.—Cohort XXIX. Olacales. Flowers actinomorphic; ovary superior, entire, one- to many-celled; seeds with copious endosperm.

Order Cyrillaceæ.—Trees and shrubs, numbering eight species, represented in the Southern United States by *Cyrilla racemiflora*, the Ironwood, and *Cliftonia ligustrina*, the Buckwheat Tree, the latter a handsome evergreen tree, three to six metres high (10 to 20 feet).

Order Ilicineæ.—The Holly Family. Trees and shrubs with mostly evergreen leaves, and three- to many-celled ovary. Species 150, of tropical and temperate climates.

Ilex Aquifolium, the Holly Tree of Europe, yields a white close-grained wood much esteemed by turners and cabinet-makers. It is sometimes blackened so as to resemble ebony. The tree, being ornamental, is extensively planted. The bright red berries remain during the winter, and with the evergreen foliage are used for Christmas decorations.

I. opaca, the American Holly, of the Southern States and the Atlantic coast from Massachusetts southward, resembles the preceding and is used for the same purposes. This and other native species are cultivated in gardens.

The leaves of *I. Paraguayensis*, a small South American tree, furnish

the Paraguay tea, sometimes called Maté. It contains Caffeine, the active principle in tea and coffee.

Order Olacineæ.—Trees and shrubs, about 170 species, almost entirely of the tropics.

598.—Cohort XXX. Geraniales. Flowers often zygomorphic; ovary superior, entire, lobed, or sub-apocarpous.

Order Chailletiaceæ.—Tropical shrubs and trees.

Order Meliaceæ.—Trees (rarely undershrubs), with mostly pinnately compound leaves; stamens united into a tube; ovary entire. Species, 270, nearly confined to the tropics.

Several trees yield valuable timber.

Melia Azedarach, the Pride of India Tree, indigenous throughout Western Asia, now naturalized in all the Mediterranean region, and the Southern United States, is a fine tree, whose reddish wood is susceptible of a beautiful finish.

Swietenia Mahogoni, a native of tropical America (barely reaching South Florida), yields the well-known Mahogany wood. The trees are of great thickness, sometimes being as much as two metres in diameter.

Cedrella odorata, of Jamaica, yields Jamaica Cedar.

C. Toona, of India, produces Chittagong wood.

C. australis, an immense Australian species, resembles the Jamaica Cedar. The wood of the three foregoing species of *Cedrella* is fine grained, and well adapted to many uses.

Chloroxylon Swietenia, of Ceylon and Western India, is a large tree, whose fine-grained satin-like wood, called Satin Wood, is much prized in cabinet and furniture making and fine turnery.

Order Burseraceæ.—Trees and shrubs, abounding in resinous or oily secretions; species, 145, nearly all tropical.

Balsamodendron Myrrha and *B. Kataf*, small Arabian trees, yield Myrrh.

B. Africanum, of Eastern Africa, produces African Bdellium.

Olibanum, an incense resin, is obtained from *Boswellia thurifera*, a lofty tree of Central India.

Bursera gummifera, West Indian Birch, of South Florida and the West Indies, yields a gum resin called Chibou or Cachibou.

Order Ochnaceæ.—Tropical shrubs and trees with a watery juice.

Order Simarubaceæ.—Shrubs and trees, with scentless foliage; leaves generally compound and alternate; stamens distinct. About 112 species, almost confined to the tropics, are known. The bitter bark and wood of many species are made use of in medicine. That from *Quassia amara*, a small tree of tropical America, is the Quassia of pharmacy. From a West Indian tree, *Simaruba amara*, the drug Simaruba Bark is obtained.

Ailanthus glandulosus, the Tree of Heaven, a native of China, is commonly planted in the United States as a shade tree. Its wood is valuable in cabinet-making.

Order Rutaceæ.—The Rue Family. Shrubs and trees, rarely herbs, with glandular-punctate heavy-scented foliage ; leaves generally compound and alternate ; stamens generally distinct. The order as here considered includes 650 known species, widely distributed in tropical

FIGS. 502-505.—ILLUSTRATIONS OF CITRUS AURANTIUM.

FIG. 502.

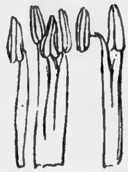


FIG. 503.

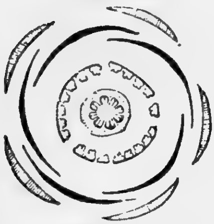


FIG. 504.

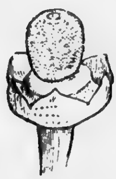


FIG. 505.

Fig. 502.—Section of flower. Magnified.
Fig. 503.—Part of andrœcium. Magnified.
Fig. 504.—Flower diagram.
Fig. 505.—Calyx and ovary. Magnified.

and temperate climates. Seven tribes, most of which were formerly considered to be orders, are recognized by Bentham and Hooker.

Tribe Aurantieæ, with actinomorphic, monoclinous flowers, baccate (berry-like) fruits, and seeds without endosperm. (Figs. 502–5.)

Citrus Aurantium, the Sweet Orange, is an Indian tree, now grown throughout all warm countries of the world for its well-known fruits.

C. Limonum, the Lemon, is a native of Northern India, now widely distributed. It was introduced into Europe during the Crusades.

Other species of *Citrus* yield valuable fruits, as *C. medica*, the Citron ; *C. Limetta*, the Lime ; *C. decumana*, the Shaddock ; *C. Bigaradia*, the Seville or Bitter Orange, etc., etc.

The hard yellow wood of the Orange is valued for inlaying

Tribe Toddalieæ, with actinomorphic, mostly diclinous flowers, coriaceous or baccate fruits, and seeds with endosperm.

Ptelea trifoliata, the Hop Tree, of the Eastern United States, *Skimmia Japonica,* a small Japanese shrub, and two species of *Phellodendron,* from Manchuria, are planted in gardens.

Tribe Xanthoxyleæ, with actinomorphic, mostly diclinous flowers, usually capsular fruits, and seeds mostly with endosperm.

Xanthoxylum Americanum, the Common Prickly Ash, of the Northern United States, and *X. Clava-Herculis,* the Southern Prickly Ash, of the Southern States, are ornamental shrubs, and are often planted.

Tribe Boronieæ.—Australian shrubs.

Tribe Diosmeæ, with actinomorphic, monoclinous flowers, capsular fruits, and seeds without endosperm.

Species of *Diosma* and *Barosma,* pretty African shrubs, are to be found in conservatories. From their leaves the drug Buchu is obtained.

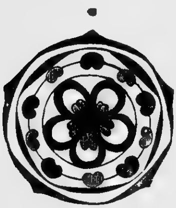


Fig. 506.—Diagram of the flower of *Dictamnus Fraxinella,* the interposed stamens (of later origin) slightly shaded.—After Sachs.

Tribe Ruteæ, with generally actinomorphic, monoclinous flowers, capsular fruits, and seeds with endosperm. (Fig. 506.)

Ruta graveolens, the Common Rue of the gardens, is a native of Southern Europe and Western Asia.

Dictamnus Fraxinella, Fraxinella, or the Gas Plant, is a heavy-scented ornamental plant, whose glandular foliage secretes a volatile oil, which is said sometimes to flash into flame when a light is brought near to it. (Figs. 116–7.)

Tribe Cusparieæ, with zygomorphic, monoclinous flowers, capsular fruits, and seeds without endosperm.

Galipea cusparia, a large tree of Guiana and Brazil, furnishes a bitter medicinal bark, known as Angustura Bark.

Order Geraniaceæ.—The Geranium Family. Mostly herbs (rarely shrubby or arborescent); leaves opposite or alternate, simple or compound; stamens more or less united below; species, 750, mostly of temperate and sub-tropical climates.

Many are cultivated as ornaments.

Impatiens Balsamina, the Garden Balsam, or Touch-Me-Not, sometimes erroneously called "Lady's Slipper," is a well-known annual from India, which has been cultivated for more than two hundred and fifty years. The name Touch-Me-Not (referring to its elastically opening fruits) is shared by two pretty native species. (Fig. 507.)

Oxalis contains several native species of Wood Sorrel, all of which

are pretty, and many exotic species (mostly South African), which are in common cultivation.

Tropæolum majus, the Nasturtium, from South America, is in common cultivation. The edible tuberous roots of *T. tuberosum*, of Peru, are used instead of potatoes in some parts of South America.

Pelargonium is another South African genus, which has furnished us with many fine greenhouse and garden flowering plants, most of which are erroneously called Geraniums.

The true Geraniums belong to the genus of that name represented in this country by eight or nine wild species.

Erodium cicutarium, the Alfilaria, of California, "is a valuable and nutritious forage plant reputed to impart an excellent flavor to milk and butter." (*Brewer.*)

Order Zygophyllaceæ.—Shrubs and herbs (a few trees), with opposite compound leaves; stamens distinct; species, about 100, almost confined to the tropics.

Guaiacum officinale, the Lignum-vitæ, of the West Indies, is a tree six to nine metres (20 to 30 feet) high, whose dark red, almost black, heartwood is exceedingly hard; it furnishes the best material for ship's blocks, pulleys, etc.

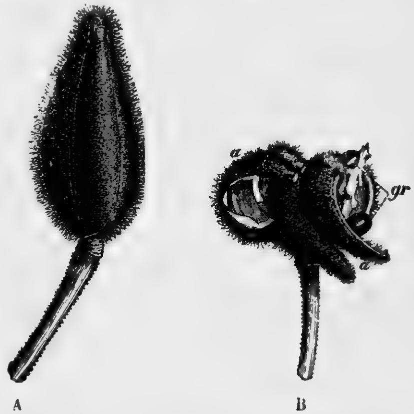


Fig. 507.—*A*, the fruit of *Impatiens Balsamina*. *B*, the same after dehiscence; *a*, *a*, carpels; *gr*, seeds. —After Duchartre.

Larrea Mexicana, the Creosote Bush of Arizona, is a curious diffusely branched evergreen shrub, with a very strong creosote-like odor.

Order Malpighiaceæ.—Trees and shrubs, often climbing; natives for the most part of the tropics; species, 580, some of which are cultivated in greenhouses.

Order Humiriaceæ.—Balsamic trees and shrubs of tropical America and Africa.

Order Linaceæ.—The Flax Family. Herbs, shrubs, and a few trees, with alternate or opposite simple leaves; stamens more or less united below; species, 135, widely distributed in temperate and tropical climates.

The most important plant of the order, and one of the most important in the vegetable kingdom, is the Flax, *Linum usitatissimum*, cultivated from time immemorial for its fibres, called linen (the bast fibres

of the cortical part of the stem). The mummy cloth of ancient Egypt is composed of flax fibres, and in the remains of the "lake dwellings" in Switzerland, fragments of linen cloth have been found. The plant appears to be indigenous in the south of Europe, as well as in the regions eastward in Asia; it is now cultivated throughout the North and South Temperate Zones. The seeds are rich in oil, which is extracted by pressure, producing the Linseed-oil of commerce; the

FIGS. 508–10.—ILLUSTRATIONS OF LINUM USITATISSIMUM.

FIG. 508.

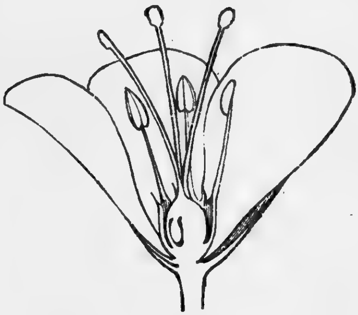


FIG 509.

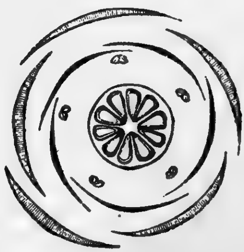


FIG. 510.

Fig. 508.—Inflorescence.
Fig. 510.—Diagram of flower.
Fig. 509.—Section of flower. Magnified.

compressed refuse is called oil-cake, and is much used as food for cattle. (Figs. 508–10.)

Erythroxylon Coca, a South American shrub, is cultivated in Bolivia and New Granada for its stimulating leaves, which are chewed like tobacco.

599.—Cohort XXXI. Malvales. Flowers usually actinomorphic; stamens indefinite, generally monadelphous; ovary

superior, generally three- to many-celled ; seeds mostly with endosperm.

Order Tiliaceæ.—The Linden Family. Trees and shrubs (a few herbs), with mostly alternate simple leaves ; stamens distinct, or somewhat united below. Species 330, mostly tropical.

Tilia Europæa, the Lime or Linden Tree of Europe and Siberia, is a large and valuable tree, yielding a soft white wood much esteemed by carvers, musical instrument makers, and others. The fibre of its bark is used for making coarse mats, and its flowers produce a great quantity of most excellent honey.

T. Americana, the American Linden, Linn, or Basswood of the Eastern United States, resembles the preceding, and is equally valuable.

While the wood of our representatives of the order is soft, that of some tropical species is very hard—*e.g., Sloanea dentata,* a West Indian tree, which has received the significant name of Break-Ax Tree.

Corchorus capsularis, a tall-growing annual of India, yields the Jute fibre now extensively used in making gunny bags, coarse carpets, and even fabrics of considerable fineness.

Figs. 511-513.—Illustrations of Theobroma Cacao.

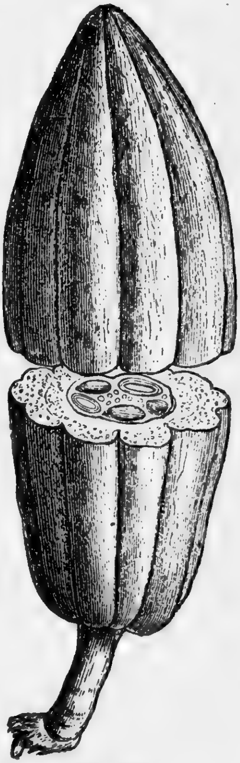


Fig. 511.

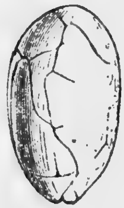


Fig. 512.

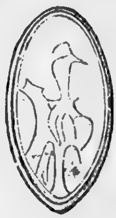


Fig. 513.

Fig. 511.—Fruit (½ natural size).
Fig. 512.—Seed. Magnified.
Fig. 513.—Seed cut vertically. Magnified.

Order Sterculiaceæ.—Trees and shrubs (a few herbs) with alternate simple or compound leaves ; stamens more or less united into a tube. The 520 species contained in this order are almost entirely tropical.

Theobroma Cacao, the Chocolate Tree of tropical America, attains a height of five to six metres (16 to 20 ft.), and bears elongated ribbed

fleshy fruits, each containing fifty or more oily seeds (Figs. 511–13). The seeds are roasted and then ground, and made into a paste and dried, constituting the Chocolate or Cocoa of commerce, according as vanilla, sugar, and other substances are, or are not added. Chocolate and Cocoa contain *Theobromine* ($C_7\ H_8\ N_4\ O_2$), an alkaloid similar to Caffeine.

Order Malvaceæ.—The Mallow Family. Herbs, shrubs, and trees, with alternate simple leaves; stamens indefinite, united into a tube;

FIGS. 514–19.—ILLUSTRATIONS OF MALVACEÆ (*Malva sylvestris*).

FIG. 514.

FIG. 515.

FIG. 516.

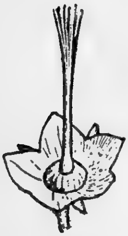


FIG. 517.

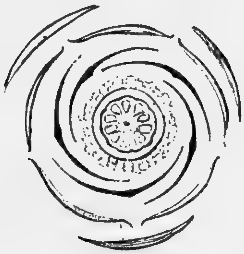


FIG. 518.

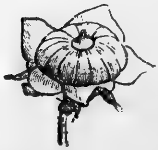


FIG. 519.

Fig. 514.—Section of flower. Magnified. Fig. 515.—Andrœcium. Magnified.
Fig. 516.—Stamen. Magnified. Fig. 517.—Calyx and pistil. Magnified.
Fig. 518.—Flower diagram. Fig. 519.—Fruit.

anthers one-celled. Species about 700, widely distributed, but most abundant in tropical regions. (Figs. 514–19.)

Gossypium herbaceum, the common Cotton Plant of tropical and subtropical countries, was probably derived originally from some part of India. Its culture by the East Indians and Egyptians was known many centuries before the Christian era. In England the manufacture and use of cotton cloth began during the latter part of the sixteenth

century. The culture of cotton in North America dates from almost the first settlements in the Southern States, and the cotton crop is now more valuable than the product of any other single cultivated plant in the United States. It is extensively cultivated in the West Indies, Brazil, Egypt, and India.

The fibre of cotton consists of greatly elongated hairs (trichomes), which develop in great numbers upon the outer surface of the seed-coats; these are at first cylindrical, but upon drying, as the seed-pod approaches maturity, they collapse and appear flat and more or less bent and twisted.

Some East and West Indian trees of the genus *Bombax* produce an abundance of a similar fibre, which is fine and silky, hence the trees are known as Silk Trees. It is said, however, that the fibre cannot be woven, and it is at present only used for stuffing cushions, etc.

The bast fibres of the stems of some species are useful. Species of *Sida* in India, China, and Australia, of *Plagianthus* in New Zealand, and of *Thespesia* and *Hibiscus* in tropical America, are thus used; from the last the fibre called Cuba Bast is obtained.

Hibiscus esculentus, the Okra or Gumbo of tropical America, produces mucilaginous edible pods, which are much used in the Southern United States.

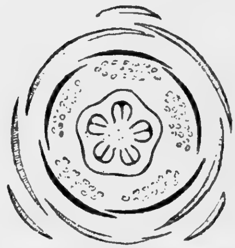


Fig. 520.—Flower diagram of *Gordonia Lasianthus*.

Species of *Durio* in the Malay Archipelago, and of *Matisia* in New Granada, furnish the inhabitants of those countries with valuable fruits. The wood of most of the species of the order is very soft and compressible; this is particularly the case with a West Indian tree, *Ochroma Lagopus*, whose wood, known as Cork Wood, has been used as a substitute for cork.

The Baobab Tree of tropical Africa is remarkable for the enormous size of its rounded spreading top and the thickness of its short stem.

Among the more common ornamental plants of the order are Mallows (*Malva*), Rose Mallow (*Hibiscus*), Hollyhock (*Althæa*), *Callirhoe*, etc.

600.—Cohort XXXII. Guttiferales. Flowers actinomorphic; stamens indefinite; ovary superior, three- to many-celled.

Order Chlænaceæ.—A few shrubs and trees of Madagascar.

Order Dipterocarpeæ.—Tropical trees (rarely shrubs), about 112 in number, the most important of which is *Dryobalanops Camphora*, the Kapor or Camphor Tree of Borneo and Sumatra, which attains a height of forty metres (130 ft.), and yields a hard red timber used in boat-building. Its resin is called Sumatra Camphor, and is much used in China and Japan.

Order Ternstrœmiaceæ.—Trees and shrubs with alternate (rarely opposite) leaves, and mostly monoclinous axillary or racemed flowers. Species 260, mostly tropical. (Figs. 520 and 521–5.)

Several ornamental species are indigenous to the Southern United States—*e.g.*, the Loblolly Bay (*Gordonia Lasianthus*, Fig 520), a tree nine to fifteen metres (30 to 50 ft.) high ; *G. pubescens*, the Mountain Bay ; and two shrubby species of *Stuartia.*

The most common exotic species cultivated for ornament is the Camellia (*Camellia Japonica*) a well-known hot-house shrub from China and Japan.

The Tea Tree (*Camellia Chinensis* or *Thea Chinensis*) is an evergreen tree three to five metres high, and a native, probably, of Southern and Eastern Asia. It has been cultivated for ages by the Chinese, and has lately been introduced to a limited extent into other countries. In preparing the leaves they are carefully picked, and then are subjected to alternate drying, pressing, rolling and airing until the proper chemical changes have taken place, and a sufficient part of the water is driven off. The different kinds and qualities of tea depend upon the rapidity of the process, and also upon the age of the leaves used, the more rapid process and the younger leaves producing the finer *green* teas, the slower process and older leaves producing the *black* teas. Somewhat appears also to depend upon the variety of the plant, there being, it is generally admitted, two varieties or races, viz., var. *viridis* and var. *Bohea.*

FIGS. 521-5.—ILLUSTRATIONS OF CAMELLIA CHINENSIS.

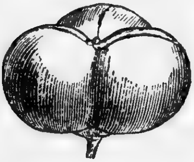


FIG. 521.

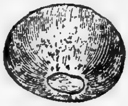


FIG. 522.

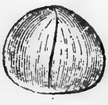


FIG. 524.

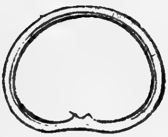


FIG. 523.

FIG. 525.

Fig. 521.—Ripe fruit. Magnified.
Fig. 522.—Seed. Magnified.
Fig. 523.—Section of seed. Magnified.
Fig. 524.—Embryo. Magnified.
Fig. 525.—Half embryo, inner face. Magnified.

Tea leaves after preparation contain the alkaloid Caffeine ($C_8 H_{10} N_4 O_2 + H_2 O$), which also occurs in roasted coffee.

Order Guttiferæ.—Trees and shrubs with yellowish or greenish resinous juice, opposite leaves, and mostly diclinous flowers. Species 230, all tropical.

Garcinia Morella, a small tree of Siam, produces Gamboge, a valuable color used in painting. Incisions are made into the bark, and the juice which exudes is gathered and dried, constituting the crude Gamboge.

The Mangosteen, a fruit about as large as an apple, and considered

to be one of the most delicious of all fruits, is produced by *Garcinia Mangostana*, a small tree of the Moluccas.

The fruit of *Mammea Americana*, a tall West Indian tree, is known as the Mammee Apple. It is as large as a melon, and its yellow pulp is said to be delicious.

A Central American species of *Calophyllum* yields a pale reddish, very durable timber known as Santa Maria wood.

Order Hypericaceæ.—Herbs and shrubs (a few trees) with opposite glandular-punctate leaves, and monoclinous flowers. Stamens united into three or five bundles (Fig. 526). Species 210, mostly found in temperate climates.

Our species are all herbs or low shrubs, belonging to the genera *Hypericum* and *Ascyrum*.

A species of *Cratoxylon*, in tropical India, is a large tree with dark brown wood.

Order Elatinaceæ.—Containing a few marsh plants.

Fig. 526.—Diagram of the flower of *Hypericum calycinum*.—After Sachs.

601.—Cohort XXXIII. Caryophyllales. Flowers actinomorphic; stamens generally definite, usually as many or twice as many as the petals; ovary superior, one-celled; placenta usually central and free; seeds with endosperm.

Order Tamariscineæ.—Mostly shrubs of the Old World, with minute alternate simple leaves.

Of the forty species, but three are found in the New World, and all these reach our extreme Southwestern border.

Tamarix Gallica, the Tamarisk of Europe to India, is a common ornamental shrub in this country.

Order Portulacaceæ.—Herbs and a few small shrubs, with alternate or opposite leaves; sepals generally two. Species 125, widely distributed, but most abundant in the New World.

Portulaca oleracea, the common Purslane, is an East Indian, or possibly South European weed. It was formerly used as a pot herb.

P. grandiflora, the Portulaca of the gardens, is a pretty flowering annual.

Claytonia and *Calandrinia*, which have many native representatives, are ornamental.

Order Caryophyllaceæ.—The Pink Family. Mostly herbs with opposite leaves; sepals four or five, free or united into a tube; placenta central. Species 800, distributed throughout the world, but most abundant in Arctic, Alpine, European, and Western Asiatic countries.

Aside from the ornamental species and the weeds, the order possesses no plants of much economic importance.

The roots of *Saponaria officinalis* contain Saponin, and are detergent, but not sufficiently so to be much used.

Among the ornamental plants are the Carnations and Clove Pinks (*Dianthus* sp.), the Mullein Pink (*Lychnis*), Catchfly (*Silene*), Bouncing Bet (*Saponaria*), *Gypsophila*, etc.

Among the weeds are species of *Cerastium* (Fig. 527), *Spergula*, and the Corn Cockle, *Lychnis Githago*. The latter is often quite abundant in wheat fields, to the great detriment of the flour manufactured from the wheat.

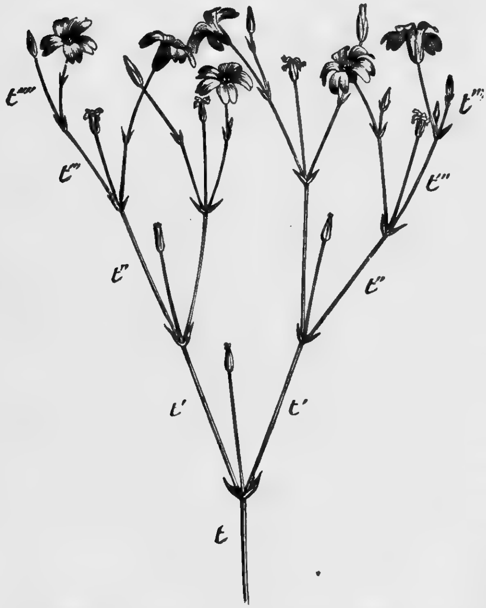


Fig. 527.—Inflorescence of *Cerastium collinum*. *t*, primary axis; *t'*, secondary axes; *t''*, tertiary axes; *t'''*, quaternary axes; *t''''*, quiuary axes.—After Duchartre.

Order Frankeniaceæ.—Maritime herbs and low shrubs resembling Caryophyllaceæ, but with parietal placentæ.

602. — Cohort XXXIV. Polygalales. Flowers actinomorphic or zygomorphic; stamens definite, as many as or twice as many as the petals; ovary usually two-celled; seeds mostly with endosperm.

Order Vochysiaceæ.—Trees with a resinous juice, and opposite or verticillate leaves; flowers zygomorphic. Species about 100, confined to tropical America.

Vochysia Guianensis, of Guiana, furnishes the Copai-ye Wood, there used for making boat-oars, the staves for sugar hogsheads, etc.

Order Polygalaceæ.—Mostly herbs with alternate leaves; flowers zygomorphic. Species 400, distributed throughout temperate and tropical countries.

A bitter principle, which is sometimes emetic and purgative, pervades the order.

Some South African species of *Polygala* are grown as ornamental plants in conservatories. A few have a little reputation as medicines.

Order Tremandreæ, containing a few Australian shrublets.

Order Pittosporaceæ.—Trees and shrubs with alternate leaves, and actinomorphic flowers; petals cohering into a tube. Species ninety, of Africa, India, China, and Australia.

Pittosporum Tobira is a common plant in conservatories.

P. undulatum, of Australia, attains a height of twenty to twenty-five metres (70 to 80 ft.), and its wood resembles Boxwood.

Climbing species of *Sollya* and other genera are grown in greenhouses.

603.—Cohort XXXV. Parietales. Flowers actinomorphic or zygomorphic; stamens definite or indefinite; ovary usually one-celled, with parietal placentæ.

Order Bixineæ.—Trees and shrubs with alternate simple leaves, actinomorphic flowers, and generally indefinite stamens; seeds with endosperm. Species 160, mostly tropical.

One or two species of *Amoreuxia* barely reach our extreme Southwestern border.

Bixia Orellana, a small South American tree now cultivated in many tropical countries, produces fruits whose orange-red pulp when prepared and dried is the valuable dye known as Arnotto.

The fruits of some species are eaten, and a few gums are derived from others.

Order Canellaceæ, containing four or five species of tropical trees.

Canella alba yields Canella Bark, which is used in medicine.

Order Violaceæ.—The Violet Family. Herbs and shrubs with mostly alternate leaves, zygomorphic flowers, and definite stamens; seeds with endosperm. Species 240, widely distributed in temperate and tropical regions.

An emetic and laxative principle is common in the plants of this order.

The genus *Viola,* the Violets, includes about half of the species of the order; many of these are indigenous to parts of the United States, and nearly all of these, as well as the exotic species, are ornamental.

V. odorata, the Sweet Violet, and *V. tricolor,* the Pansy, both natives of Europe, are common in gardens and door-yards. Of the latter there are almost numberless varieties.

Several Brazilian shrubby plants of the order are cultivated in greenhouses.

The root of *Ionidium Ipecacuanha,* a Brazilian shrub, is the White Ipecacuanha of pharmacy.

A Peruvian tree, *Leonia glycycarpa*, produces edible pulpy fruits as large as a peach.

Order Cistaceæ.—Herbs and shrubs with actinomorphic flowers. Species about sixty, mostly of temperate climates.

A shrubby *Cistus* from the South of Europe is common in greenhouses.

Some of our native species of Frostweed (*Helianthemum*) and *Hudsonia* are pretty.

Order Resedaceæ.—Herbs (a few shrubs) with alternate leaves, mostly zygomorphic flowers, indefinite stamens, and seeds without endosperm. Species twenty to twenty-five, confined to the Mediterranean region and South Africa, with the exception of two or three spe-

FIGS. 528–30.—ILLUSTRATIONS OF CRUCIFERÆ (WALLFLOWER).

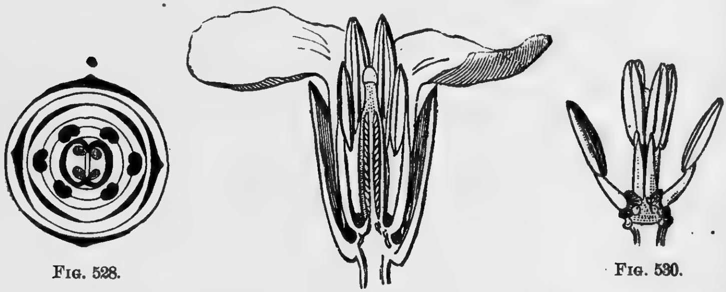


FIG. 528. FIG. 529. FIG. 530.

Fig. 528.—Flower diagram. Fig. 529.—Section of Flower. Magnified. Fig. 530.—Andrœcium. Magnified.

cies which reach India, one of which (*Oligomeris subulata*) extends to California.

Reseda odorata is the well-known Mignonette, probably a native of the Eastern Mediterranean region.

The foliage of *R. luteola,* an annual of Europe called Dyers' Weed or Weld, furnishes an important yellow dye.

Order Capparidaceæ.—Herbs, shrubs and trees with mostly alternate leaves, actinomorphic flowers, mostly indefinite (never tetradynamous) stamens, and seeds without endosperm. Species 300, mostly tropical or sub-tropical. An acrid volatile principle prevails in the order.

Capparis spinosa, a stiff prickly-branched shrub of the Mediterranean region, is extensively cultivated in Europe for its unopened flower buds, which preserved in vinegar constitute the condiment known as Capers.

Cleome integrifolia, a native of the Western Mississippi Valley, and

C. pungens, of South America, are fine flowering plants cultivated in gardens.

Order Cruciferæ.—The Crucifer Family. Herbs and a few low shrubs with actinomorphic flowers, tetradynamous stamens, and seeds without endosperm (Figs. 528–41). This large order includes 172 genera and about 1200 species, which are distributed throughout the temperate regions of the world, but are most abundant in Southern Europe and Asia Minor. The prevailing principle in the order is pungent and stimulant.

The order is divided by Bentham and Hooker into ten tribes, distinguished by the shape of the fruit and the disposition of the cotyledons in the seed, whether incumbent or accumbent (Figs. 536 to 541).

The order furnishes a few food plants of some importance.

Brassica oleracea, a wild plant of the Atlantic coast of Europe, is

FIGS. 531-5.—ILLUSTRATIONS OF CRUCIFERÆ (SHEPHERD'S PURSE).

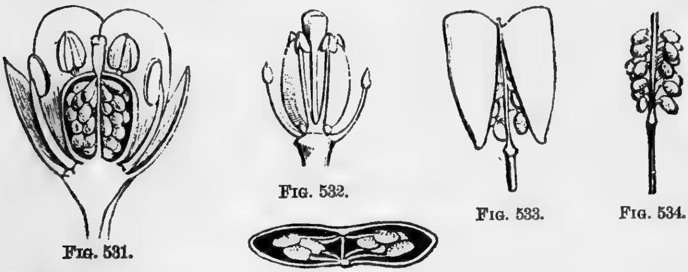


FIG. 531. FIG. 532. FIG. 533. FIG. 534. FIG 535.

Fig. 531.—Vertical section of flower. Magnified.
Fig. 532.—Pistil and stamens. Magnified.
Fig. 533.—Ripe capsule splitting open. Magnified.
Fig. 534.—Seeds on placentæ, the capsule-valves removed. Magnified.
Fig. 535.—Cross-section of capsule. Magnified.

probably the original form from which have been derived by long cultivation the following races, which are now almost, if not quite, entitled to be regarded as species, differing as they do fully as much from one another as many wild species :

Race I. Cauliflower, in which the thickened and consolidated flower peduncles constitute the edible portion of the plant.

Race II. Bore Cole or Kale, in which the expanded but tender leaves of the tall stem are the edible parts.

Race III. Brussels Sprouts, resembling the last, but with thick edible buds in the axils of the leaves.

Race IV. Cabbage, in which the leaves do not expand, but form a single large thick edible bud or "head."

Race V. Kohl-Rabi, in which the short and few-leaved stem becomes thick, bulbous, and edible.

B. campestris, of the same regions as the preceding, has given rise to the various kinds of Turnips. Colza and Rape also are probably varieties; the latter are extensively cultivated in Europe for their oily seeds, from which useful oils are obtained by pressure.

Raphanus sativus, the Radish, is a native of China.

Nasturtium Armoracia, the Horseradish of Europe, has long been cultivated for its pungent roots, which are used as a condiment. According to Dr. Gray, the plant, for some unknown reason, does not produce seeds in this country.

N. officinale, Water Cress of Europe, and now run wild in many parts

Figs. 536-41.—Seeds of Cruciferæ.

Fig. 536.

Fig. 537.

Fig. 538.

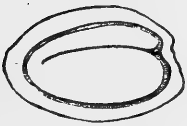


Fig. 539.

Fig. 540.

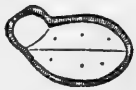


Fig. 541.

Fig. 536.-Seed of *Erysimum.* Magnified.
Fig. 537.—Longitudinal section of seed. Magnified.
Fig. 538.—Cross-section of seed, showing incumbent cotyledons. Magnified.
Fig. 539.—Longitudinal section of seed of *Arabis.* Magnified.
Fig. 540.—Cross-section of seed of *Arabis*, accumbent cotyledons. Magnified.
Fig. 541.—Cross-section of seed of *Barbarea*, imperfectly accumbent cotyledons. Magnified.

of the United States, and many other rapidly growing foreign and native species, are used as salads.

Brassica alba, White Mustard, and *B. nigra,* Black Mustard, both natives of Europe, are grown for their seeds, which when ground constitute the common condiment Mustard. It is also of considerable value in medicine.

Isatis tinctoria, a tall-growing European biennial, was formerly extensively grown for the blue dye obtained from it.

The most important ornamental plants of the order are the Wallflower (*Cheiranthus*), Gilly Flower or Brompton Stock (*Matthiola*), Rocket (*Hesperis*), Candytuft (*Iberis*), Honesty (*Lunaria*), Sweet Alyssum (*Alyssum*), etc., etc.

Several of the species are troublesome weeds—*e g.*, Shepherd's Purse (*Capsella*), which has come to this country from the Old World; Peppergrass (*Lepidium*), native and introduced; False Flax (*Camelina*) from Europe; Charlock and Mustard (*Brassica*) from Europe.

The curious plant called the Rose of Jericho (*Anastatica hierochuntica*), often sold as a curiosity, is a small annual, native of Arabia, Egypt, and Syria. The mature plant after ripening its seeds contract into a rounded mass, and is uprooted and blown about by the wind. When, however, the dry and dead plant is moistened, it expands, closing again when dry. On this account it is also called the Resurrection Plant.

FIGS. 542-5.—ILLUSTRATIONS OF PAPAVER RHŒAS.

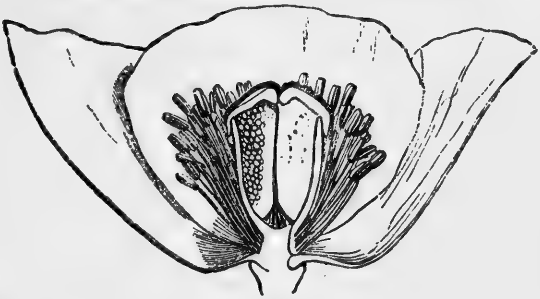


FIG. 542.

FIG. 543.

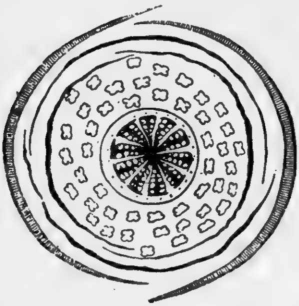


FIG. 544.

FIG. 545.

Fig. 542.—Vertical section of flower. Magnified.
Fig. 543.—Pistil and stamen. Magnified.
Fig. 544.—Flower diagram.
Fig. 545.—Ripe fruit.

Order Fumariaceæ.—Herbs with watery juice, alternate, usually divided leaves; flowers zygomorphic; stamens definite, four, five or six and diadelphous. Species about 100, natives of warmer portions of the North Temperate Zone and of South Africa. They possess an acrid and astringent principle.

Bentham and Hooker, in the "Genera Plantarum," unite this order

with the next, but this arrangement has not generally been adopted by botanists.

Dicentra spectabilis, the Bleeding Heart, a showy Chinese species, is in common cultivation for its heart-shaped pink-red flowers. Our native species, *D. Canadensis* and *D. Cucullaria*, are pretty, and are sometimes cultivated.

Climbing Fumitory (*Adlumia cirrhosa*) is a delicate native climber, also cultivated in gardens.

Order Papaveraceæ.—The Poppy Family. Herbs and a few low shrubs, with a milky or colored juice, alternate leaves, and actinomorphic flowers; stamens indefinite, seeds with endosperm (Figs. 542–5). The order as here constituted includes about sixty species, natives, for the most part, of the North Temperate Zone. They contain a narcotic principle.

The most important plant of the order is the Opium Poppy (*Papaver somniferum*), a native of many parts of the Old World, and now cultivated in Southern Europe and India. Opium is obtained from it by scarifying the full-grown but still green capsules; the juice which exudes soon hardens and is then collected, constituting in this state the crude Opium of commerce.

Opium contains from six to twelve per cent of an alkaloid substance, Morphia ($C_{17}\ H_{19}\ N\ O_3 + H_2\ O$), to which its narcotic properties are mainly due.

Other species of *Papaver*, several of which are in common cultivation in flower-gardens, contain Opium, but it is not considered to be as valuable as that from the Opium Poppy.

Sanguinaria Canadensis, the Blood-root, a pretty native plant of the Eastern United States, contains in its red juice narcotic properties similar to those of Opium.

Among the ornamental plants besides Poppies and Blood-root, are *Bocconia*, a tall-growing Chinese perennial, *Argemone*, from Mexico, and *Eschscholtzia*, from California.

Order Sarraceniaceæ.—Perennial marsh herbs, with radical tubular leaves, solitary actinomorphic flowers; stamens indefinite; seeds with endosperm. Species ten, nine of which are natives of the United States. (Figs. 546–7.)

Sarracenia purpurea, the common Pitcher Plant of the Northern and Eastern United States, inhabits peat bogs and "cranberry marshes." Its open, pitcher-like leaves contain water, in which many decaying insects may always be found. The structure of the interior surface of the pitcher is such as to make it exceedingly difficult for insects, when once in it, to escape, being lined for some ways down with myriads of short and sharp stiff bristles which point downwards. Without doubt these plants are nourished by the decaying insects in their leaves, and to this extent they are to be regarded as saprophytes. In some Southern species, as, for example, *S. variolaris* and *S. psittacina*, the pitcher is

covered by a hood much as in *Nepenthes* (page 483), and in these water is also found (undoubtedly a secretion in these cases) in which are many decaying insects. Moreover, in these and some other species drops of a sweetish honey-like substance are secreted on the leaves, which apparently serve to lure insects to the margin of the pitcher.

The California Pitcher Plant (*Darlingtonia Ca ifornica*) of the northern part of California, has long tubular leaves which are arched over at

Fig. 547.

the top, so that the orifice opens downward; from the orifice there hangs down a forked blade, which is more or less covered with a sweet secretion, and within the tube there is always found water more or less filled with insects. The arrangement here is evidently one well fitted to capture insects, which, after maceration, are absorbed for the nourishment of the plant.

Fig. 546.—Flower and leaves of *Sarracenia purpurea*. ⅓ natural size.—From Le Maout and Decaisne.
Fig. 547.—Pistil cut vertically.—From Le Maout and Decaisne.

The third genus, *Heliamphora,* contains a single species, native of Venezuela.

604.—Cohort XXXVI. Ranales.—Flowers mostly actinomorphic; stamens rarely definite; carpels free, very rarely connate; seeds with copious endosperm.

Order Nymphæaceæ.—The Water Lily Family. Aquatic herbs, with usually floating peltate leaves; flowers solitary, monoclinous; petals and stamens generally numerous; carpels mostly united, rarely free. Species thirty-five, widely distributed.

Nelumbium luteum, the Yellow Water Lily, or Water Chinquepin, is common in the ponds and rivers of the Mississippi Valley and the Southern States. Its nut-like fruits, which are imbedded in the large top-shaped receptacle, are edible. (Figs. 548–9.)

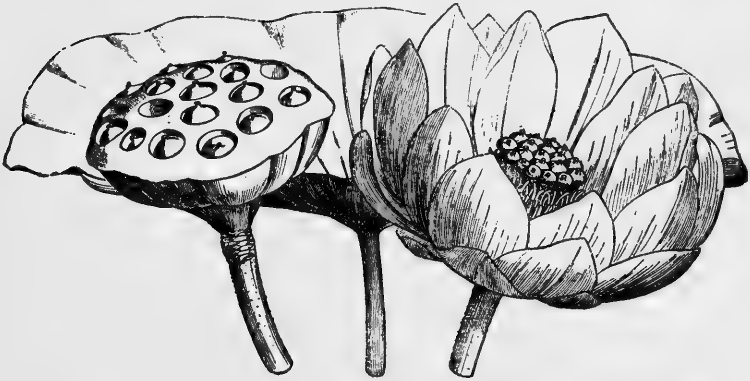


Fig. 548.—Leaf, flower, and fruiting receptacle of *Nelumbium luteum*. ⅛ natural size.—From Le Maout and Decaisne.

N. speciosum, the only other species of the genus, occurs in Southern and Southeastern Asia.

Nymphæa odorata and *N. tuberosa* are the well-known White Water Lilies of the Eastern United States. *N. cærulea* and *N. Lotus* are common on the Nile.

Victoria regia, the Victoria Lily of the Amazon Valley in South America, is remarkable for the size of its leaves and flowers; the former are peltate, perfectly circular, and two metres or more in diameter, and the slender petioles are often three metres long; the flowers resemble those of our White Water Lilies, and are twenty-five to thirty centimetres in diameter; upon first opening they are pure white, but upon opening a second time they are of a pink color.

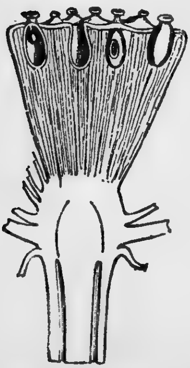


Fig. 549.—Section of the young receptacle and carpels.

Order Berberidaceæ.—The Barberry Family. Herbs and shrubs with alternate or radical leaves; flowers monoclinous or diclinous; petals and stamens few; carpels one to three, rarely more, distinct. Species about 100, mostly natives of cool climates.

Berberis vulgaris, the Barberry of Europe (Figs. 550–3), is cultivated as an ornamental shrub, as well as for its edible acid berries. The flowers are interesting on account of their sensitive stamens, which

move quickly toward the pistil when touched at their bases by an insect searching for the honey secreted by glands upon the petals (Figs. 551–52).

B. Canadensis, of the Southern States, is much like the foreign species.

FIGS. 550–3.—ILLUSTRATIONS OF BERBERIS VULGARIS.

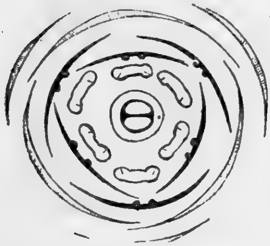


FIG. 550.


FIG. 551.

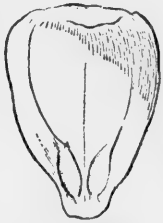


FIG. 552.

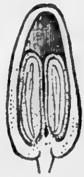


FIG. 553.

Fig. 550.—Flower diagram.
Fig. 551.—Pistil, with a petal and stamen. Magnified.
Fig. 552.—Upper side of a petal, showing its two glands. Magnified.
Fig. 553.—Vertical section of ovary. Magnified.

Several evergreen species from the Rocky Mountains and Oregon, and one from Japan, are cultivated under the name of Mahonia.

Podophyllum peltatum, the May Apple of the Eastern United States, produces an edible, plum-shaped fruit. Its poisonous rootstocks are

FIGS. 554–8.—ILLUSTRATIONS OF MENISPERMUM CANADENSE.

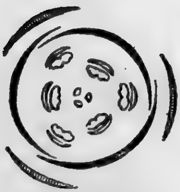


FIG. 554.


FIG. 555.

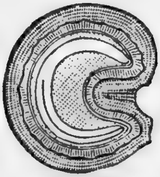


FIG. 556.


FIG. 557.

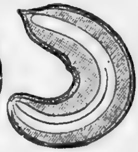


FIG. 558.

Fig. 554.—Diagram of male flower.
Fig. 555.—Fruit. Magnified.
Fig. 556.—Section of fruit. Magnified.
Fig. 557.—Seed. Magnified.
Fig. 558.—Section of seed. Magnified.

used somewhat in medicine. A second species occurs in the Himalayas.

Caulophyllum thalictroides, of the Eastern United States and also of Japan, is interesting on account of its young ovaries bursting open and allowing the ovules to develop into naked drupe-like seeds.

Order Menispermaceæ.—Woody twining plants, with alternate leaves; flowers diclinous; petals usually six, with a stamen before (opposite to) each one; carpels usually three, distinct and one-seeded. Species eighty to one hundred, principally tropical. They generally contain a bitter principle, which in some is tonic, in others narcotic, or even poisonous.

Menispermum Canadense, the Moonseed of the Eastern United States, is a beautiful climber deserving cultivation in ornamental gardens. Its only congener is a native of Eastern Asia. (Figs. 554–8.)

FIGS. 559–64.—ILLUSTRATIONS OF ASIMINA TRILOBA.

FIG. 559.

FIG. 560.

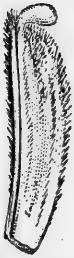


FIG. 561.

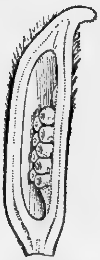


FIG. 562.

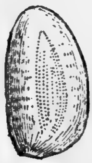


FIG. 563.

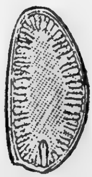


FIG. 564.

Fig. 559.—Section of flower. Magnified.
Fig. 560.—Flower diagram. Magnified. Fig. 561.—Young carpel. Magnified.
Fig. 562.—Section of young carpel. Magnified.
Fig. 563.—Seed. Natural size. Fig. 564.—Section of seed.

Two other genera, *Calycocarpum* and *Cocculus*, are represented in the United States.

Many of the Old World species are more or less in repute as furnishing medicines, but none are of sufficient importance to be particularly noticed.

Order Anonaceæ.—Trees and shrubs with alternate leaves; flowers trimerous; stamens indefinite, on a thickened receptacle; carpels generally indefinite. Species 400, mostly tropical. The bark generally contains an aromatic and stimulating, sometimes acrid principle.

Asimina triloba, the Papaw of the Southern United States, and extending to the Great Lakes, is a small tree producing edible pulpy fruits six to ten centimetres long. Several other smaller species of the same genus are common in the South. (Figs. 559–564.)

Anona reticulata, the Custard Apple, *A. Cherimolia*, the Cherimoya, *A. squamosa*, Sweet Sop, and *A. muricata*, Sour Sop, all cultivated in the West Indies and tropical America, produce edible fruits; the first is regarded by some people as one of the finest fruits in the whole world.

Xylopia aromatica is a tree of western tropical Africa, whose dry carpels are aromatic, and used as pepper under the name of Guinea Pepper. The ancients used this pepper ("Piper Æthiopicum") long before the introduction of Black Pepper.

FIGS. 565–7.—ILLUSTRATIONS OF MAGNOLIA PURPUREA.

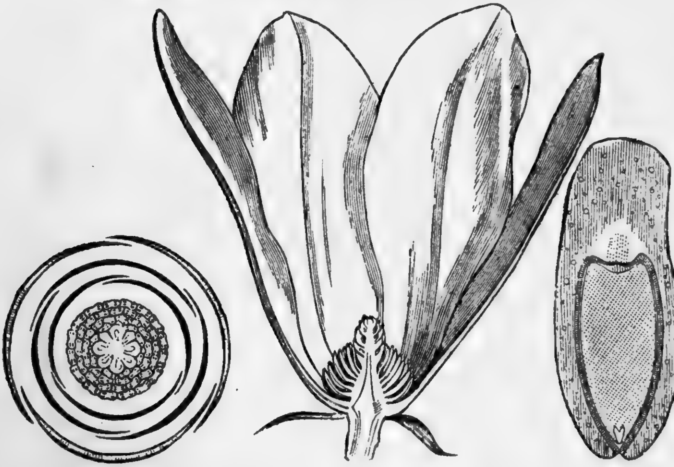


FIG. 566. FIG. 565. FIG. 567.

Fig. 565.—Flower cut vertically. Fig. 566.—Flower diagram.
Fig. 567.—Section of seed. Magnified.

Duguetia quitarensis, a small tree of Guiana, supplies a tough elastic wood known as Lancewood.

Order Magnoliaceæ.—The Magnolia Family. Trees and shrubs with alternate simple leaves; flowers mostly monoclinous; petals and stamens indefinite; carpels usually indefinite. Species seventy, mostly of the tropical and sub-tropical parts of Asia and America. (Figs. 566–7.)

The genus *Magnolia* contains many beautiful trees, seven of which are natives of the Southern United States. Of these *M. acuminata*, the Cucumber Tree, extends north to the Great Lakes, and sometimes at-

tains a height of forty to fifty metres. Its light, whitish wood is valuable, and is much used for many purposes.

M. grandiflora is much like the preceding, but has larger flowers and evergreen leaves, the former being from fifteen to twenty-five centimetres in diameter. It grows only in the Southern States, where its timber is somewhat used.

M. Umbrella and *M. macrophylla* are named Umbrella Trees on account of the way in which their large leaves spread from the ends of the branches. The leaves of the last-named species are from fifty to eighty centimetres (20 to 30 in.) long, and the flowers are from thirty to thirty-five centimetres (12 to 14 in.) in diameter.

M. glauca, the Sweet Bay, is a shrubby species extending from Louisiana to Massachusetts, in the north near the coast only.

The foregoing and most, if not all, the remaining species are quite ornamental, and are planted wherever they will endure the winters.

Liriodendron Tulipifera, the Tulip Tree or Yellow Poplar of the Eastern United States, is one of our largest and most valuable timber trees. Its light, whitish or yellowish wood is much used in cabinet-making, coach-building, and for many other purposes.

Magnolia conspicua is the Yulan Tree of China. Other species of this genus occur in Japan, China, and the Himalaya region.

Order Calycanthaceæ.—Shrubs with opposite leaves; seeds without endosperm. Three species occur in the Southern United States, one in California, and one in Japan. This order, the structure of which cannot be discussed here, is evidently out of place in this Cohort.

Order Dilleniaceæ.—Shrubs, rarely trees, with alternate leaves; sepals five, petals five; stamens indefinite; ovaries usually distinct, one-celled. Species 180, mostly tropical.

Two Californian species of the genus *Crossosoma*, doubtfully referred to this order, are our only representatives.

Some of the Indian species of *Dillenia* and *Wormia* yield hard and valuable timber.

Order Ranunculaceæ.—Herbs, rarely shrubs, with mostly alternate or radical leaves; sepals usually five or fewer, deciduous, often petaloid; petals in one whorl, often wanting; carpels usually distinct. (Figs. 568–73.) Species about 500, most abundant in temperate and cold regions. The herbage usually possesses a considerable acridity.

Formerly many of the species were reputed to be of medicinal value, but at the present day they are but little used except by quacks. Several species, however, still retain their places in the pharmacopœias; among these are:

Aconitum Napellus, Monkshood or Aconite, a native of Europe, whose roots furnish the drug Aconite.

A. ferox, of upper India, supplies the people of that region with a virulent poison, with which they poison their arrows.

Helleborus niger, Black Hellebore, *H. fœtidus*, Stinking Hellebore,

FIGS. 568-73.—ILLUSTRATIONS OF RANUNCULACEÆ (*Caltha palustris*).

FIG. 568.

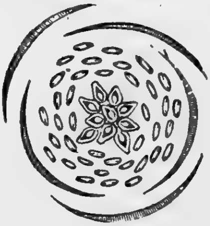


FIG. 570.

FIG. 571.

FIG. 572.

FIG. 569.

FIG. 573.

Fig. 568.—Flowering stem.
Fig. 570.—Flower diagram.
Fig. 572.—Seed. Magnified.
Fig. 569.—Vertical section of flower.
Fig. 571.—Young carpel. Magnified.
Fig. 573.—Section of seed. Magnified.

and *H. viridis*, Green Hellebore, all natives of Europe, furnish drastic and poisonous drugs.

Among the ornamental plants of the order may be mentioned the following:

Anemone, of several species, including our native Hepaticas, now placed in this genus.

Adonis, the Pheasant's Eye, of Europe.

Aquilegia, the Columbine, including our common Eastern species (*A. Canadensis*) and the Rocky Mountain Long Spurred Columbine (*A. cœrulea*), as well as the common one of Europe (*A. vulgaris*).

Clematis, the Virgin's Bower, of many species, native and foreign, all pretty.

Delphinium, the Larkspur, of many species, mostly foreign.

Nigella, Love in a Mist, from the Old World.

Pæonia, the Peony, of several species, from Europe, Siberia, and China.

Ranunculus, Buttercup, of several European species.

Trollius, Globe Flower, from Europe and Siberia.

Very few species afford nutritious products useful for food; the tuberous roots of a species of *Ranunculus* are gathered and eaten in some parts of Central Europe, and a few fleshy species (as, for example, *Caltha palustris*, *Ranunculus sceleratus*, etc.) are used to a limited extent as pot herbs.

Fossil Dicotyledons.—No Dicotyledons are known in the periods earlier than the Cretaceous. In this, however, many modern orders are represented. In the Cretaceous of the Western Territories of the United States Lesquereux describes* one hundred species of Dicotyledons. Of these sixty belong to the Apetalæ, five to the Gamopetalæ, and thirty-five to the Choripetalæ (Polypetalæ). The Apetalæ include five species of *Populus*, six of *Salix*, eight of *Quercus*, six of *Platanus*, seven of *Sassafras*, etc. Among the remarkable fossils are a species of *Ficus* from Minnesota, two species of *Cinnamomum* from Kansas, and two of *Laurus* from Nebraska. The five species of Gamopetalæ represent the Ericaceæ (a single species of *Andromeda*), Ebenaceæ (two species of *Diospyros* from Kansas and Nebraska), and Sapotaceæ (two species, one a *Bumelia* from Nebraska and Minnesota). Among the species of Choripetalæ are five of *Magnolia*, two of *Liriodendron*, one of *Hedera*, one of *Prunus*, one of *Pirus*, etc., from Kansas, Nebraska, and Dakota.

In the Tertiary most of the more important orders of Dicotyledons are represented. Here, as in the Cretaceous, there is still a predominance of Apetalous species; thus in the Tertiary Flora of the Western Territories† there have been determined of the Apetalæ one hundred and twelve species, Gamopetalæ, nineteen, and Choripetalæ, seventy-nine. The Apetalæ are principally represented by the Myricaceæ (twelve species of *Myrica*), Betulaceæ, Cupuliferæ (a *Carpinus*, a *Corylus*, a *Fagus*, a *Castanea*, and eighteen species of *Quercus*), Juglandaceæ

* "Contributions to the Fossil Flora of the Western Territories. Part I., The Cretaceous Flora," by Leo Lesquereux. Washington, 1874.

† Leo Lesquereux, op. cit. Part II., "The Tertiary Flora," 1878.

(a *Carya*, a *Pterocarya*, and seven species of *Juglans*), Salicaceæ (four species of *Salix* and twelve of *Populus*), Platanaceæ (five species of *Platanus*), Moraceæ (twenty-three species of *Ficus*), Lauraceæ (six species of *Laurus*, one of *Tetranthera*, and four of *Cinnamomum*).

The Gamopetalæ are represented by Caprifoliaceæ (nine species of *Viburnum*), Oleaceæ (four species of *Fraxinus*), Ebenaceæ (four species of *Diospyros*), and Ericaceæ (an *Andromeda* and a *Vaccinium*).

The principal orders of the Choripetalæ are Ampelideæ (one species of *Ampelopsis*, two of *Vitis*, and four of *Cissus*), Anacardiaceæ (five species of *Rhus*), Cornaceæ (four species of *Cornus*), Rhamnaceæ (ten species of *Rhamnus*, five of *Zizyphus*, three of *Paliurus*, and one of *Berchemia*), Ilicineæ (four species of *Ilex*), Sapindaceæ (six species of *Sapindus*), Myrtaceæ (two doubtful species of *Eucalyptus*), Rosaceæ (a single species of *Cratægus*), Leguminosæ (a *Podogonium*, a *Cassia*, an *Acacia*, a *Mimosites*, and two *Leguminosites*), and Magnoliaceæ (four species of *Magnolia*).

CHAPTER XXI.

CONCLUDING OBSERVATIONS.

605.—The Number of Species of Plants.—It is impossible at the present time to give with even approximate accuracy the number of existing species of plants. In the first place, a great many species in all parts of the world are as yet undescribed; even in England, where the study of this branch of Botany has been most energetically pursued, many new species are discovered every year. In the central and western countries of the continent of Europe, as in England, while comparatively few flowering plants have escaped detection, there yet remain undescribed hundreds of species of the lower groups, and in the regions eastward there are doubtless many phanerogams as well as cryptogams which have not yet been enumerated. A complete "Flora of Europe" will probably be an impossibility for very many years. In Asia our knowledge of the plants is still more fragmentary. Japan and India, with parts of Asia Minor, are the best known botanically, but even in these regions our knowledge is almost entirely confined to the phanerogams and higher cryptogams. In Australia and the islands to the northward and in Africa, there are enormous tracts which have not yet been explored. In the New World, from Mexico southward, the descriptions and enumerations of the native plants are scattered through many works, not one of which approximates completeness even for comparatively small regions. In North America, the "Flora of North America," begun forty years ago, is yet unfinished, even for the flowering plants.*

* "A Flora of North America," by John Torrey and Asa Gray. Vol. I., 1838–40. Vol. II. (in part), 1843. Resumed under the title of "A Synoptical Flora of North America," by Asa Gray, 1878.

In the second place, many of the so-called species in descriptive works are but varieties, while in other cases the same forms have been described under different names. This is true in all the groups of plants, and scarcely a monograph now appears in which there are not cases of the reduction of a supposed species to a synonym or variety.

606.—With these considerations in mind, we may examine the catalogues and make some general estimates. Steudel in 1824 catalogued in "Nomenclator Botanicus" 59,684 phanerogams and 10,965 cryptogams, making a total of 70,649. In the second edition, published in 1841, the number of phanerogams was increased to about 78,000. Lindley, in 1845, estimated the number of dicotyledons to be 66,488, the monocotyledons 13,952, and the cryptogams 12,480, making a total of 92,820. De Candolle's "Prodromus," begun in 1824 and continued to 1873, contains, according to Alph. De Candolle's historical note in Vol. XVII. of that work, descriptions of 58,446 dicotyledons and 429 gymnosperms.

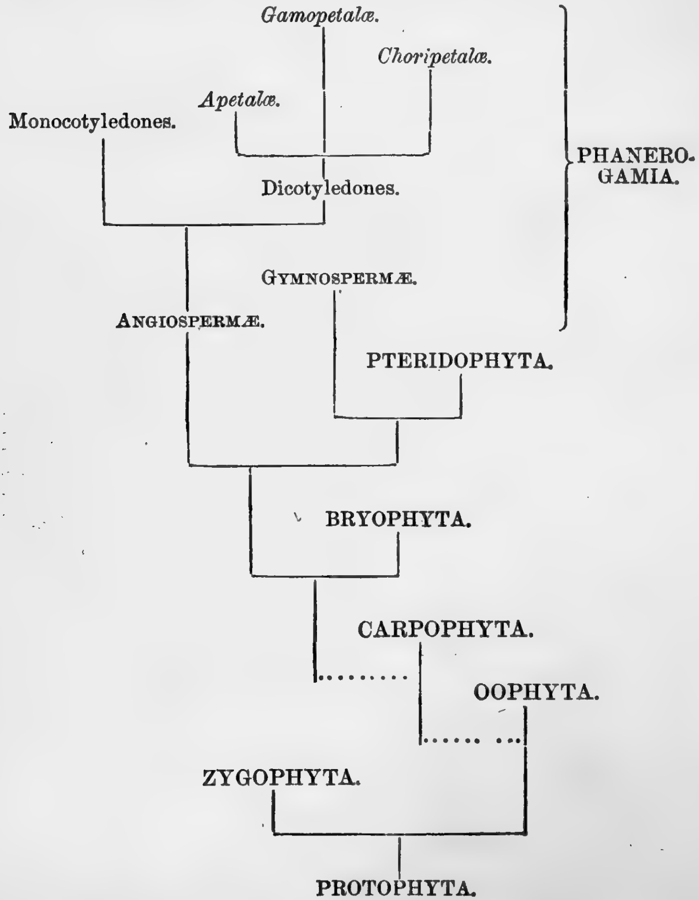
Duchartre estimates the known species of phanerogams at about 100,000, and of cryptogams at about 25,000, and ventures to place the whole number of species in the world at from 150,000 to 200,000. Dr. Gray quotes De Candolle's estimate of the known species of flowering plants, amounting to from 100,000 to 120,000, and says that "the larger number may perhaps include the higher orders of the flowerless series," and in speaking of the lower cryptogams says that at present "no close estimate can be well formed of the actual number of species."*

607.—The Affinities of the Groups of Plants.—Many attempts have been made to construct diagrammatic figures which should indicate the affinities of the different groups of the vegetable kingdom. While it is impossible to do this with any great degree of accuracy, we may yet show in this way certain relations, more clearly than can be done otherwise. The subjoined diagram may be taken to indicate in a general way the writer's present notion of the affinities (*i.e.*,

---

* In his "Botanical Text-Book," 1879, Part I., p. 346, foot-note.

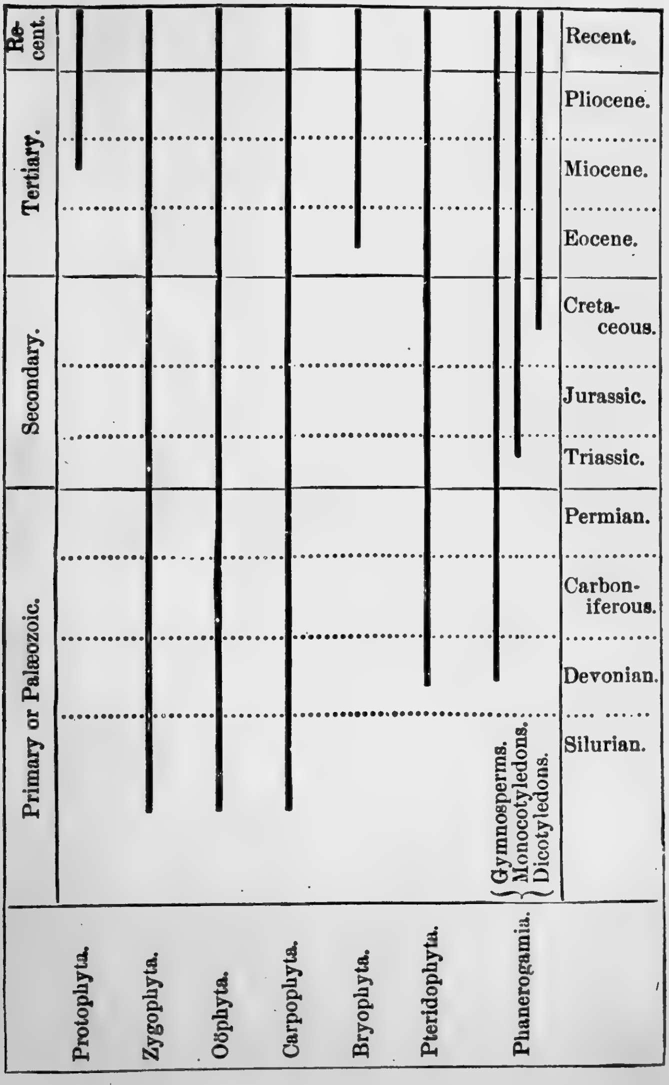
the genetic relations) of the seven great divisions of plants, so far as they can be shown upon a plane surface :



608.—The Distribution of Plants in Time. If we bring together what is yet known as to Fossil Botany (Phytopalæontology), as has been done by Schimper,* we find that the

* "Traité de Paléontologie Végétale," par W. Ph. Schimper. Paris, 1869 to 1874. This work of three large octavo volumes (aggregating 2696 pp.) and a quarto atlas of 110 plates is a most valuable one for the student of Phytopalæontology.

TABULAR VIEW OF THE DISTRIBUTION IN TIME OF THE DIVISIONS OF THE VEGETABLE KINGDOM.



several Divisions of the Vegetable Kingdom are very unequally distributed in geologic time. Thus no fossil Protophyta have yet been discovered earlier than the Tertiary (Miocene), while the Zygophyta, Oophyta, and Carpophyta, with scarcely any doubt, were well represented in the Silurian. Bryophyta have not been detected in strata earlier than the Eocene (Tertiary), while Pteridophyta extend back to the Devonian. Of the Phanerogamia the Gymnosperms originated in the Devonian, the Monocotyledons in the Triassic, and the Dicotyledons in the Cretaceous. These facts may be more clearly shown by the table on the preceding page.

It must be borne in mind that our knowledge of fossil plants is as yet extremely limited, a comparatively small portion only of the earth's strata having hitherto been carefully examined. It is very probable that as we come to know more of the fossil remains of plants some or all of the lines in the table will be extended downward. On the other hand, we need not expect to find many remains of the exceedingly simple organisms which constitute the Protophyta, although they probably have existed in abundance since pre-Silurian times. So, too, few Zygophytes have a sufficiently durable plant-body to allow them to be preserved in a fossil state. The softness of texture and easy perishability of the tissues of the Bryophyta, especially in the lower orders, probably accounts for the few fossil remains hitherto discovered. Doubtless we must in the same way account for the fact that most of the species of fossil Phanerogams are trees and shrubs; the softer tissues of the herbaceous species have yielded but few fossils as compared with the harder and denser ones of the ligneous species.

INDEX TO THE ILLUSTRATIONS.

GENERAL INDEX.

THE AMERICAN SCIENCE SERIES.

THE principal objects of the series are to supply the lack—in some subjects very great—of authoritative books whose principles are, so far as practicable, illustrated by familiar American facts, and also to supply the other lack that the advance of Science perennially creates, of text-books which at least do not contradict the latest generalizations. The scheme systematically outlines the field of Science, as the term is usually employed with reference to general education, and includes ADVANCED COURSES for maturer college students, BRIEFER COURSES for beginners in school or college, and ELEMENTARY COURSES for the youngest classes. The Briefer Courses are not mere abridgments of the larger works, but, with perhaps a single exception, are much less technical in style and more elementary in method. While somewhat narrower in range of topics, they give equal emphasis to controlling principles. The following books in this series are already published:

THE HUMAN BODY. By H. NEWELL MARTIN, Professor in the Johns Hopkins University.

Advanced Course. 8vo. 655 pp.

Designed to impart the kind and amount of knowledge every educated person should possess of the structure and activities and the conditions of healthy working of the human body. While intelligible to the general reader, it is accurate and sufficiently minute in details to meet the requirements of students who are not making human anatomy and physiology subjects of special advanced study. *The regular editions of the book contain an appendix on Reproduction and Development. Copies without this will be sent when specially ordered.*

From the CHICAGO TRIBUNE: "The reader who follows him through to the end of the book will be better informed on the subject of modern physiology in its general features than most of the medical practitioners who rest on the knowledge gained in comparatively antiquated text-books, and will, if possessed of average good judgment and powers of discrimination, not be in any way confused by statements of dubious questions or conflicting views."

THE HUMAN BODY.—*Continued.*

Briefer Course. 12mo. 364 pp.

Aims to make the study of this branch of Natural Science a source of discipline to the observing and reasoning faculties, and not merely to present a set of facts, useful to know, which the pupil is to learn by heart, like the multiplication-table. With this in view, the author attempts to exhibit, so far as is practicable in an elementary treatise, the ascertained facts of Physiology as illustrations of, or deductions from, the two cardinal principles by which it, as a department of modern science, is controlled,—namely, the doctrine of the "Conservation of Energy" and that of the "Physiological Division of Labor." To the same end he also gives simple, practical directions to assist the teacher in demonstrating to the class the fundamental facts of the science. *The book includes a chapter on the action upon the body of stimulants and narcotics.*

From HENRY SEWALL, *Professor of Physiology, University of Michigan:* "The number of poor books meant to serve the purpose of text-books of physiology for schools is so great that it is well to define clearly the needs of such a work: 1. That it shall contain accurate statements of fact. 2. That its facts shall not be too numerous, but chosen so that the important truths are recognized in their true relations. 3. That the language shall be so lucid as to give no excuse for misunderstanding. 4. That the value of the study as a discipline to the reasoning faculties shall be continually kept in view. I know of no elementary text-book which is the superior, if the equal, of Prof. Martin's, as judged by these conditions."

Elementary Course. 12mo. 261 pp.

A very earnest attempt to present the subject so that children may easily understand it, and, whenever possible, to start with familiar facts and gradually to lead up to less obvious ones. *The action on the body of stimulants and narcotics is fully treated.*

From W. S. PERRY, *Superintendent of Schools, Ann Arbor, Mich.:* "I find in it the same accuracy of statement and scholarly strength that characterize both the larger editions. The large relative space given to hygiene is fully in accord with the latest educational opinion and practice; while the amount of anatomy and physiology comprised in the compact treatment of these divisions is quite enough for the most practical knowledge of the subject. The handling of alcohol and narcotics is, in my opinion, especially good. The most admirable feature of the book is its fine adaptation to the capacity of younger pupils. The diction is simple and pure, the style clear and direct, and the manner of presentation bright and attractive."

ASTRONOMY. By SIMON NEWCOMB, Professor in the Johns Hopkins University, and EDWARD S. HOLDEN, Director of the Lick Observatory.

Advanced Course. 8vo. 512 pp.

To facilitate its use by students of different grades, the subject-matter is divided into two classes, distinguished by the size of the type. The portions in large type form a complete course for the use of those who desire only such a general knowledge of the subject as can be acquired without the application of advanced mathematics. The portions in small type comprise additions for the use of those students who either desire a more detailed and precise knowledge of the subject, or who intend to make astronomy a special study.

From C. A. YOUNG, *Professor in Princeton College:* "I conclude that it is decidedly superior to anything else in the market on the same subject and designed for the same purpose."

Briefer Course. 12mo. 352 pp.

Aims to furnish a tolerably complete outline of the astronomy of to-day, in as elementary a shape as will yield satisfactory returns for the learner's time and labor. It has been abridged from the larger work, not by compressing the same matter into less space, but by omitting the details of practical astronomy, thus giving to the descriptive portions a greater relative prominence.

From THE CRITIC: "The book is in refreshing contrast to the productions of the professional schoolbook-makers, who, having only a superficial knowledge of the matter in hand, gather their material, without sense or discrimination, from all sorts of authorities, and present as the result an *indigesta moles*, a mass of crudities, not unmixed with errors. The student of this book may feel secure as to the correctness of whatever he finds in it. Facts appear as facts, and theories and speculations stand for what they are, and are worth."

From W. B. GRAVES, *Master Scientific Department of Phillips Academy:* "I have used the Briefer Course of Astronomy during the past year. It is up to the times, the points are put in a way to interest the student, and the size of the book makes it easy to go over the subject in the time allotted by our schedule."

From HENRY LEFAVOUR, *late Teacher of Astronomy, Williston Seminary:* "The impression which I formed upon first examination, that it was in very many respects the best elementary text-book on the subject, has been confirmed by my experience with it in the class-room."

ZOOLOGY. By A. S. PACKARD, Professor in Brown University.

Advanced Course. 8vo. 719 pp.

Designed to be used either in the recitation-room or in the laboratory. It will serve as a guide to the student who, with a desire to get at first-hand a general knowledge of the structure of leading types of life, examines living animals, watches their movements and habits, and finally dissects them. He is presented first with the facts, and led to a thorough knowledge of a few typical forms, then taught to compare these with others, and finally led to the principles or inductions growing out of the facts.

From A. E. VERRILL, *Professor of Zoology in Yale College:* "The general treatment of the subject is good, and the descriptions of structure and the definitions of groups are, for the most part, clear, concise, and not so much overburdened by technical terms as in several other manuals of structural zoology now in use."

Briefer Course. 12mo. 334 pp.

The distinctive characteristic of this book is its use of the *object method.* The author would have the pupils first examine and roughly dissect a fish, in order to attain some notion of vertebrate structure as a basis of comparison. Beginning then with the lowest forms, he leads the pupil through the whole animal kingdom until man is reached. As each of its great divisions comes under observation, he gives detailed instructions for dissecting some one animal as a type of the class, and bases the study of other forms on the knowledge thus obtained.

From HERBERT CSBORN, *Professor of Zoology, Iowa Agricultural College:* "I can gladly recommend it to any one desiring a work of such character. While I strongly insist that students should study animals from the animals themselves,—a point strongly urged by Prof. Packard in his preface,—I also recognize the necessity of a reliable text-book as a guide. As such a guide, and covering the ground it does, I know of nothing better than Packard's."

First Lessons in Zoology. 12mo. 290 pp.

In method this book differs considerably from those mentioned above. Since it is meant for young beginners, it describes but few types, mostly those of the higher orders, and discusses their relations to one another and to their surroundings. The aim, however, is the same with that of the others; namely, to make clear the general principles of the science, rather than to fill the pupil's mind with a mass of what may appear to him unrelated facts.

ZOOLOGY—*Continued.*

From SCIENCE :—The style is clear, and the subjects made interesting. The student's mind is not confused by a mass of details, or by unsatisfactory descriptions of a large number of specimens which he can never expect to see, much less examine; but the brief sketches of a few of the most important forms will awaken in him a desire for wider knowledge. The figures are numerous, averaging almost one to each page; yet they are so well selected that, while one grudges so much space, he finds few which he would omit.

BOTANY. By CHARLES E. BESSEY, Professor in the University of Nebraska.

Advanced Course. 8vo. 611 pp.

Aims to lead the student to obtain at first-hand his knowledge of the anatomy and physiology of plants. Accordingly, the presentation of matter is such as to fit the book for constant use in the laboratory, the text supplying the outline sketch which the student is to fill in by the aid of scalpel and microscope.

From J. C. ARTHUR, Editor of *The Botanical Gazette:* "The first botanical text-book issued in America which treats the most important departments of the science with anything like due consideration. This is especially true in reference to the physiology and histology of plants, and also to special morphology. Structural Botany and classification have up to the present time monopolized the field, greatly retarding the diffusion of a more complete knowledge of the science."

Essentials of Botany. 12mo. 292 pp.

A guide to beginners. Its principles are, that the true aim of botanical study is not so much to seek the family and proper names of specimens as to ascertain the laws of plant structure and plant life; that this can be done only by examining and dissecting the plants themselves; and that it is best to confine the attention to a few leading types, and to take up first the simpler and more easily understood forms, and afterwards those whose structure and functions are more complex. *The latest editions of the work contain a chapter on the Gross Anatomy of Flowering Plants.*

From J. T. ROTHROCK, *Professor in the University of Pennsylvania:* "There is nothing superficial in it, nothing needless introduced, nothing essential left out. The language is lucid; and, as the crowning merit of the book, the author has introduced throughout the volume 'Practical Studies,' which direct the student in his effort to see for himself all that the text-book teaches."

CHEMISTRY. By IRA REMSEN, Professor in the Johns Hopkins University.

Advanced Course. 8vo. 828 pp.

The general plan of this work will be the same with that of the Briefer Course, already published. But the part in which the members of the different families are treated will be considerably enlarged. Some attention will be given to the lines of investigation regarding chemical affinity, dissociation, speed of chemical action, mass action, chemical equilibrium, thermochemistry, etc. The periodic law, and the numerous relations which have been traced between the chemical and physical properties of the elements and their positions in the periodic system will be specially emphasized. Reference will also be made to the subject of the chemical constitution of compounds, and the methods used in determining constitution.

Introduction to the Study of Chemistry. 12mo. 389 pp.

The one comprehensive truth which the author aims to make clear to the student is the essential nature of chemical action. With this in view, he devotes the first 208 pages of the book to a carefully selected and arranged series of simple experiments, in which are gradually developed the main principles of the subject. His method is purely inductive; and, wherever experience has shown it to be practicable, the truths are drawn out by pointed questions, rather than fully stated. Next, when the student is in a position to appreciate it, comes a simple account of the theory of the science. The last 150 pages of the book are given to a survey, fully illustrated by experiments, of the leading families of *inorganic* compounds.

From ARTHUR W. WRIGHT, *Professor in Yale College*:—The student is not merely made acquainted with the phenomena of chemistry, but is constantly led to reason upon them, to draw conclusions from them, and to study their significance with reference to the processes of chemical action—a course which makes the book in a high degree disciplinary as well as instructive.

From THOS. C. VAN NUYS, *Professor of Chemistry in the Indiana University*:—It seems to me that Remsen's "Introduction to the Study of Chemistry" meets every requirement as a text or class book.

From C. LES MEES, *Professor of Chemistry in the Ohio University*:—I unhesitatingly recommend it as the best work as yet published for the use of beginners in the study. Having used it, I feel justified in saying this much.

CHEMISTRY—*Continued.*

Elements of Chemistry. 12mo. 272 pp.

Utilizes the facts of every-day experience to show what chemistry is and how things are studied chemically. The language is untechnical, and the subject is fully illustrated by simple experiments, in which the pupil is led by questions to make his own inferences. The author has written under the belief that "a rational course in chemistry, whether for younger or older pupils, is something more than a lot of statements of facts of more or less importance; a lot of experiments of more or less beauty; or a lot of rules devised for the purpose of enabling the pupil to tell what things are made of. If the course does not to some extent help the pupil to think as well as to see it does not deserve to be called rational."

CHASE PALMER, *Professor in the State Normal School, Salem, Mass.:*—It is the best introduction to chemistry that I know, and I intend to put it into the hands of my pupils next Fall.

A. D. GRAY, *Instructor in Springfield (Mass.) High School:*—Neat, attractive, clear, and accurate, it leaves little to be desired or sought for by one who would find the best book for an elementary course in our High Schools and Academies.

GENERAL BIOLOGY. By WILLIAM T. SEDGWICK, Professor in the Mass. Institute of Technology, and EDMUND B. WILSON, Professor in Bryn Mawr College. *Part I.* 8vo. 193 pp.

This work is intended for college and university students as an introduction to the theoretical and practical study of biology. It is not zoology, botany, or physiology, and is intended not as a substitute, but as a foundation, for these more special studies. In accordance with the present obvious tendency of the best elementary biological teaching, it discusses broadly some of the leading principles of the science on the substantial basis of a thorough examination of a limited number of typical forms, including both plants and animals. Part First, now published, is a general introduction to the subject illustrated by the study of a few types. Part Second will contain a detailed survey of various plants and animals.

W. G. FARLOW, *Professor in Harvard University, Cambridge, Mass.:*—An introduction is always difficult to write, and I know no work in which the general relations of plants and animals and the cell-structure have been so well stated in a condensed form.

POLITICAL ECONOMY. By FRANCIS A. WALKER, President of the Massachusetts Institute of Technology.

Advanced Course. 8vo. 537 pp.

"The peculiar merit of this book is its *reality.* The reader is brought to see the application of the laws of political economy to real facts. He learns the extent to which those laws hold good, and the manner in which they are applied. The subject is divided, as usual, into the three great branches of production, exchange, and distribution. An interesting and suggestive book on consumption is added, which serves to bring in conveniently the principles of population. The last part of the volume is given to the consideration of various practical applications of economic principles to such questions as those of Banking, Coöperation, Trades' unions, Strikes, Bimetallism, and Protection."—*The Boston Advertiser.*

Briefer Course. 12mo. 402 pp.

The demand for a briefer manual by the same author for the use of schools in which only a short time can be given to the subject has led to the publication of the present volume. The work of abridgment has been effected mainly through excision, although some structural changes have been made, notably in the parts relating to distribution and consumption.

From RICHARD T. ELY, *Professor in the Johns Hopkins University:* —"Let one who proposes to teach political economy master, first of all, F. A. Walker's Political Economy."

From the CHRISTIAN UNION:—"Professor Walker is not only an authority in his department, but he is an admirable teacher. His definitions are remarkably clear; and though he throws out of his calculations all other than merely economic considerations, he does so avowedly, and continuedly reminds the student that other considerations do exist—a respect for ethics not always paid by preceding writers in the same field. He is also more modern, and shows a more lively appreciation of the living facts of to-day, than most writers of text-books on the subject"

From THE ACADEMY, *London:*—"With the merits of brevity and clearness, it combines those of forcible statement and original thought. In a condensed, yet readable shape, it presents all the chief doctrines hitherto ascertained in political economy; and summarizes with great fairness the arguments on both sides, on those facts which are matters of debate rather than doctrine."

HENRY HOLT & CO., PUBLISHERS, N. Y.